COLLEGE OF BIOLOGICAL AND PHYSICAL SCIENCES

SCHOOL OF BIOLOGICAL SCIENCES

A TRAINING MODULE FOR

EXTERNAL DEGREE PROGRAMME

BACHELOR OF EDUCATION (SCIENCE)

BIOLOGY

BASIC ENTOMOLOGY- UNIT SZL 404

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1.1 Unit Introduction

This Unit is intended to introduce the student of Zoology to the study of one group of animals; the insects. Insects belong to the group of Invertebrate animals called Arthropoda. This group comprises at least 85 per cent of all known animals and includes such familiar forms as crabs, shrimps, spiders, and centipedes, as well as the true insects (Insecta). The Unit will expose the student to the subject referred to as "Entomology" which simply means the study of Insects. The great Diversity of Insects and the various types of habitats exploited by insects will become evident as the different types of insect groups are mentioned. Basic information on Insect structures and how these relate to functions will be emphasized. General aspects on Insect evolution, Ecology, Social behaviour, Development and Metamorphosis will be mentioned as basic information, upon which much more specialized studies may be based. The last part of the Unit will focus on and the economic importance of insects.

The unit is divided broadly into five parts namely the classification and morphology; systemics; development; ecology and the relationship between insects and man. There are a total of twenty specific lectures with increasing levels of complexity reflective of phylogenetic relationships among the various insect groups. Illustrations have been provided where applicable and lecture objectives have been stated at the beginning of each lecture. Revision questions, Activity portions, and summaries are included in the Unit to facilitate comprehension of unit contents as well as you prepare you for final examinations.

The practical aspects of the unit are contained in a separate Manual.

Objectives

At the end of this unit you should be able to:

1. Identify common Insects and classify them into their respective taxa (orders)
2. Describe the external morphology and internal Anatomy of a typical Insect
3. Relate the various insect body structures to their functions
4. Identify the developmental stages of insects.
5. Differentiate the different types of development stages exhibited by various insect groups.
6. Describe the various social organization among insects.
7. State the economic importance of Insects
8. Discuss Insect origin, behaviour and ecology.
9. Describe the various social organization among insects.
10. State the economic importance of Insects.

LECTURE1: INSECTS AND RELATED ARTHROPODS

Objectives

At the end of this lecture you should be able to;

- Define the terms Taxonomy, Entomology and Species
- Name taxa used in the classification of living organisms.
- State the criteria used to grouping insects.
- List features of the phylum Arthropoda and class Insecta.
- Describe other classes of phylum Arthropoda related to class Insecta.
- Name the taxa used in the classification of insects

1.1: Introduction to the study of insects

Insects comprise the most diverse group of animals on the earth, with 800,000 species described, more than all other animals groups combined. Insects may be found in nearly all environments on the planet, but with few species in oceans. There are approximately 5,000 dragon fly species, 2,000 praying mantis, 20,000 grasshopper, 170,000 butterfly and moth, 120,000 fly, 80,000 true bug, 350,000 beetle, and 110,000 bee and ant species.

In this lecture we shall learn that the study of insects has a special name known as Entomology. We shall relate the insects to their closest relatives as we classify them under a broader category known as Phylum Arthropoda. We shall begin by identifying key features
unique to the Phyla. Finally we shall examine the distinguishing features of the class Insecta and examine some of the criteria used in the classification of specific insects such as the common house fly. There are several numbered activities for you. Take all of them and check the correct answers in the appendices where applicable. Note that some activities are purely practical exercises and therefore do not have answers appended.

**Question**

- Can you still remember that the study of insects is called **ENTOMOLOGY**?

### 1.1.1: Importance of classification

Have you ever thought about why we name things at all? If you have you probably realized, names are very important for identifying things, especially when communicating with other people. However not everybody uses the same name for the same animal. For instance “Rwagi”, “mbuu” and “Suna” are all different names for the mosquito in different parts of Kenya. These are known as **common names** and can vary so much thereby causing confusion. It is for this reason that Carl Linnaeus in the 1750’s suggested a method of naming things that could be used by scientists all over the world.

He introduced the binomial nomenclature, which means two names. The two names were both in Latin. The first name identifies the **genus** and the second the **species**. A fly such as the housefly is scientifically known as *Musca domestica* although it has many different names in different parts of the world. Such scientific names follow a specific format. Because the names are Latin, they often appear in italics. Note that the first letter to the Genus is always capitalized.

The science of naming things is called **taxonomy** and though it can become quite complicated the basics are easy to understand. There are rules governing the naming of animals. These rules are referred to as the International Code of Zoological Nomenclature (ICZN). The current provisions of ICZN are set out in 87 articles grouped into 18 Chapters further to the International Congress of Zoology, 1961 – 64. The code consists of mandatory rules some of them operating only from specific dates, together with non-mandatory recommendations.

Now that we know what taxonomy is let us look at classification categories:

Any classification category or unit regardless of its level is called a **taxon**

### 1.1.2: Criteria for classification

Below are the various taxonomic categories beginning from the broader groupings to the most specific groups:

- **ANIMALIA**
- **KINGDOM**
- **PHYLUM**
- **Subphylum**
- **CLASS**
- **Subclass**
- **Superorder**
- **ORDER**
- **Suborder**
- **Superfamily**
- **FAMILY**
- **Subfamily**
- **Tribe**
- **Subtribe**
- **GENUS**
- **Subgenus**
- **SPECIES**
- **Subspecies**

Take note that not all the taxa are always used; but you are expected to be familiar with the taxa indicated above in block letters.

Animals belong to approximately thirty six (36) phyla.

Insects are classified based on morphology and Phylogeny. Phylogeny refers to the evolutionary relationships between living organisms.

**ACTIVITY 1.1**

(All answers available under Appendices)

1. Re write the taxa but this time starting with the species............................................
2. The study of insects is called..............................................................
3. The science of naming living things is called...........................................
4. Any classification category is referred to as a .................................
5. Animals belong to approximately.........................number of phyla (2, 36, 120, 2000)

FAOyieke
Phylum

All organisms within a kingdom are then divided into groups based on common characteristics. The living members of the kingdom Animalia are divided into approximately 36 smaller groups called phylaphylum. One such phylum is known as Arthropoda. Arthropoda is a Greek word that means "jointed foot". The phylum Arthropoda is of interest to us because this is where insects belong. It contains animals that generally have the following features:

1. Having a characteristic tough chitinous protective exoskeleton flexible only at the joint.
2. Having the nervous system running along the ventral side of the body.
3. Growing by ecdysis or molting.
4. Bearing pairs of legs along all or part of length of the body, which are modified for different functions.
5. Nervous system of a dorsal brain connected to a ventral double nerve cord.
6. Possessing reduced coelomic body cavities called haemocoels, often filled with blood.
7. Respiration by gills, book lungs or trachea.
8. Sexes separate (dioecious).
9. Excretion by mandibular glands, labial glands or Malphigian Tubules.

Question

Are insects members of the phylum Arthropoda?

Class

Phylum is a very broad classification and is therefore broken down into smaller taxa called Classes. Arthropoda contain the following classes:

1. Trilobita - These are extinct animals that had a pair of antennae, a pair of eyes and many biramous appendages.
2. Crustacea - These include the Lobsters, Crabs and Woodlice.
3. Diplopoda - These are the millipedes.
4. Chilopoda - These are the centipedes
5. Symphyla - these are centipede-like animals.
6. Pauropoda - the pauropods.
7. Chelicerata (Arachnida) - Spiders, Scorpions, ticks and mites.
8. Insecta (Uniramia) - the true insects, such as beetles, bees, and butterflies.

Note that centipedes, millipedes, Symphylans and pauropods are collectively referred to as Myriapods. These arthropods have long trunks with many segments and appendages, most of which are walking legs.

Since we are interested in insects let us look at the features of members in the class Insecta more detail.

1.1.2.2; class Insecta
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5. **Symphyla** - These are centipede-like animals.
6. **Pauropoda** - The paurapods.
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Since we are interested in insects let us look at the features of members in the class Insecta more detail.

**1.1.2.2.1**: features of the class Insect

**Features of the class Insecta**

Insects are the largest and the most widely distributed taxon within the phylum Artropoda.

Insects are referred as invertebrates because they lack a backbone.

The class Insecta is characterized by the following features:

1. Body with well-defined head, thorax and abdomen. Abdomen may be separated by constrictions.
2. Head of a number (probably 6) fused segments.
3. Thorax of 3 segments and abdomen of 11 segments, primitively, and a vestigial telson.
4. Head appendages are pair each of antennae, mandibles, 1st maxillae and 2nd maxillae (fused medially to form a labium).
5. Each thoracic segment bears a pair of legs and in apterygote insects, a pair of wings on each of 2nd and 3rd thoracic segments, (one or both pairs lost in some insects or non functional flight).
6. Except in the apterygote insects, there are no abdominal appendages except on the genital segments.
7. Appendages (where present), on 11th segments, are called cerci.
8. External body form varies greatly in different orders.
9. Where soft-bodies (e.g. caterpillars), the unsclerotised cuticle is held taut by internal pressure of blood (hydrostatic skeleton).
10. They are tracheate.
11. They have exposed mouthparts

The three body regions and other features of the class Insecta are represented in Fig. 1.1 below:

Fig. 1.1 General external morphology of an insect.
ACTIVITY 1.2

This is a practical activity to be done in a practical book to be submitted to the tutor during the residential phase of the course.

1. Using any insect that is locally available and with the help of a hand lens, examine the insect and identify all the parts labeled in the diagram above.

1.2.2.3: Orders of the class Insecta

The next subdivision is orders. The uniramia or insecta are divided into even smaller, though still pretty large groups called orders. For example, the housefly belongs to the order Diptera.

The other Insect groups (Orders) that exist are listed below: Further descriptions and illustrations of these orders will be covered in lectures 17 and 18 and also in the practical part for this course unit.

Order 1. Thysanura (Silverfish, Bristle-tails, Fire Brats)
Order 2. Diplura (some Bristle tails)
Order 3. Protura (cone heads)
Order 4. Collembola (Spring-tails)
Order 5. Ephemeroptera (Mayflies)
Order 6. Odonata (Dragonflies)
Order 7. Dictyoptera (Cockroaches and praying mantids)
Order 8. Isoptera (Termites)
Order 9. Plecoptera (Stoneflies)
Order 10. Grylloblattodea (small rare group)
Order 11. Dermaptera (Earwigs)
Order 12. Phasmida (Stick and Leaf-insects)
Order 13. Orthoptera (Crickets and grasshoppers)
Order 14. Embioptera (Web-spinners)
Order 15. Zoraptera (small rare group)
Order 16. Psocoptera (Book-lice and Psocids)
Order 17. Thysanoptera (Thrips)
Order 18. Mallophaga (Biting Lice)
Order 19. Anoplura (Sucking lice)
Order 20. Hemiptera (Bed bugs)
Order 21. Neuroptera (Ants; lions, Lace-wings, Alderflies etc.)
Order 22. Mecoptera (Scorpionflies)
Order 23. Tricoptera (Caddisflies)
Order 24. Lepidoptera (Butterflies and Moths)
Order 25. Diptera (flies, mosquitoes, fruit flies, tsetse flies)
Order 26. Siphonaptera (Fleas)
Order 27. Hymenoptera (Bees, Wasps, Ants, etc.)
Order 28. Coleoptera (Beetles)
Order 29. Strepsiptera (twisted wing parasites)
Order 30. Homoptera (Aphids, scale insects, leafhoopers)

ACTIVITY 1.3

Have you encountered any of the insects listed above?

If your answer is no, then collect at least ten different insects that are representative of ten different orders and present your findings as tabulated above.

If your answer is yes, then present your answer in a tabular form. i.e. list the common names against the respective orders.

1.1.2.4: Family, Genus and species

Orders are then divided into families. For example, within the order Diptera (the flies) there are several families; within each family several genera and within each genus a number of species.

The hierarchy used to classify the house fly or honey bee scientifically, is as follows:

Phylum - Arthropoda

Class - Insecta
Order - Diptera

Family - Muscidae for housefly and Apidae for honeybee.

Genus - Musca for housefly and Apis for honeybee.

species domestica for housefly and mellifera for honeybee.

This universal method is used to prevent confusion among geographic regions of the world. Consequently, Musca domestica refers to the same insect species in Kenya as it does in Asia or anywhere else in the world. Similarly Apis mellifera refers to the same insect species in Kenya as it does in Asia or anywhere else in the world.

The Species

A species may be defined as a group of individuals or a population in nature that are capable of interbreeding and producing fertile offspring, and under natural conditions, are reproductively isolated from other such groups, i.e., they do not interbreed.

The species is the lowest category in the classification hierarchy. It is a critical category, because the grouping of individuals into species is the most specific level of classification. Most often, insect species are classified based on similarities in appearance (morphology).

Is it necessary to group insects under specific groups/names?

YES! It is necessary to classify insects so that we can organize what we know about them and determine their relationships with other animals, plants and with man.

summary

- The study of insects is called Entomology.
- There are advantage of using scientific names as opposed to common names of insects. The advantage is that scientific names do not change from region to region and are therefore useful worldwide.
- The science of naming living things is called Taxonomy.
- Animals can be classified based on Phylogeny and morphology.
- Insects are so diverse that they can be grouped into about 30 different orders based on morphological characteristics.
- There is a hierarchy of classifying insects. Using such a hierarchy we have been able to classify the common house fly and honey bee.
- Arthropods are characterized by a chitinous exoskeleton and a linear series of segments some of which bear jointed appendages.
- Within the phylum Arthropoda there are several classes namely Trilobita (extinct), Crustacea, Arachnida, Pauropoda, Symphila, Diplopoda, Chilopoda and Insecta.
- The class Insecta is characterized by three body regions, a tracheal system, possession of antennae, three thoracic segments, each bearing a pair of legs, at least 11 abdominal segments, and one or two pairs of wings.
- The grasshopper or locust or cockroach can be used as models to study the general morphological features insects.

LECTURE2: INSECT EXTERNAL MORPHOLOGY: THE EXOSKELETON

Objectives

At the end of this lecture we should be able to:

- Illustrate the structure of the insect integument.
- State the functions of the insect cuticle.
- Relate the structure of the integument to its function.
- Discuss how the exoskeleton has contributed to the success of Insects.
- Indicate how the integument has been modified in various insect groups.

2.0: Introduction

In lecture one we learned that one of the distinctive features of Arthropods including insects is the possession of the exoskeleton.

In this lecture we shall describe the features of the insect exoskeleton and examine how it has contributed to the success of insects as a group.

2.1: The Exoskeleton

2.2: The exoskeleton

In insects and other arthropods the skeleton is on the outside. It is therefore, called exoskeleton.

The exoskeleton is the hard outer covering made mostly of a substance called chitin.

The best way for you to get a feel of the exoskeleton is to examine any beetle that you can find. A beetle looks like a bean seed. Imagine that the outer coat of a bean seed is equivalent to the exoskeleton covering the back of a beetle.

Now that you have seen the exoskeleton, we can continue to describe it in more detail.

The exoskeleton together with the epidermis and basement membrane form the insect body wall also known as the Integument. The insect integument is composed of four layers, which, are described and presented in figure 2.1 below:

2.3: The insect integument.

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Now that you have seen the exoskeleton, we can continue to describe it in more detail.

The exoskeleton together with the epidermis and basement membrane form the insect body wall also known as the Integument. The insect integument is composed of four layers, which, are described and presented in figure 2.1 below:

Fig. 2.1 The insect Integument
Based on the above diagram the key components of the insect integument are:

a. ..................................................

b. ..................................................

c. ..................................................

d. ..................................................

2.4 The epidermis

The epidermis is the outer cell layer. It is a single cell layer derived from the embryonic ectoderm. The cross section of an epidermal cell is almost hexagonal and closely packed tiger the. The cells vary at different sites. They also vary among different species in height and shape from cuboidal to columnar to irregular. The epidermis secretes the cuticle. It plays the key role in ecdysis by secreting the molting fluid. The fluid loosens the cuticle from the cell layers through enzymatic action. It also absorbs the resulting digested products.

2.5 The basement membrane

The epidermal cells stand on the basement membrane. The basement membrane is an extremely thin, entirely continuous sheet. It is composed of flattened satellite cells these are loosely bound together with intracellular material. This membrane resembles the connective tissue of vertebrates although it has no fibers.

2.6 The cuticle

The cuticle is a secretion of the epidermis that covers the whole of the outside of the insect body and is also a lining of the foregut, hindgut and trachea.

The cuticle is hard due to a horny substance called sclerotin. The process of hardening of the cuticle is called sclerotization. Certain areas of the cuticle however contain an elastic protein called resin, which provides the elasticity of the cuticle. The cuticle is laminated and consists of the layers stated below.

2.6.1 The endocuticle

This is the layer next to the epidermis. Between the epidermis and the endocuticle is an amorphous layer called the Schmidt’s layer.

2.6.2 The exocuticle
The executable contains a substance called sclerotin. The color of an insect is due to pigments in the body wall. These pigments are usually in the exocuticle.

2.6.3: The procuticle

The procuticle is laminated and strengthened by vertical diagonal rods of homogeneous composition. It is penetrated by minute, helical canals known as pore canals. These lead to the outer layers. Chitin, a nitrogenous polysaccharide is a characteristic constituent of the practice. Chitin is more abundant in the softer parts.

2.6.4: The epicuticle

The Epicuticle consists of four layers as follows:

- An innermost cuticulin layer which contains lipoproteins
- A waxy layer (randomly oriented wax)
- A waxy layer (evenly oriented waxy monolayer)
- An outermost cement layer (epicuticula)

Molecules of the monolayer are very closely packed. This provides the waterproof layer of the cuticle. The cement layer is very thin and outside the waxy layer. It is absent in insects with scales.

The epicuticle is impermeable to water and therefore protects the insect from desiccation.

**ACTIVITY 2.2**

1. The process of hardening of the cuticle is called…………………..
2. Other than being on the outside body of the insect, the cuticle lines the ………………………………………………………………………………….
3. Which layer of the integument contributes to waterproofing the integument?

2.7: Functions and modifications of the cuticle

The cuticle is one of the features of insects, which is primarily responsible for their success in that:

1. It plays an important part in **supporting** the insects.
2. The hard jointed appendages made of cuticle make **movements** possible with minimum muscles. This results in economy of muscles.
3. **Flight** in insects depends on the rigidity in the wings. The cuticle provides this rigidity.
4. Parts of the cuticle are modified to form **sense organs**.
5. **Protection** from predators, parasites, harsh environment, and dehydration is provided by the cuticle.

**Summary**

In this lecture we have learnt that: -
• The insect skeleton is on the outside and is called the exoskeleton.
• The exoskeleton, basement membrane and epidermis form the insect body wall.
• The exoskeleton provides insects with adequate protection against mechanical injuries, enemies, infections and water loss.
• The cuticle is hardened by a substance known as sclerotin through a process referred to as sclerotization.
• The cuticle is made up of several layers comprising of endocuticle, exocuticle, procuticle and epicuticle.
• The cuticle has pigments, a waxy component in addition to having some degree of elasticity and flexibility.
• The cuticle is responsible for the success of insects as it contributes to the following: body protection, body support, movement, and flight.
• Parts of the cuticle have been modified to form sense organs.
• The cuticle is shed off during molting to permit growth of immature stages of insects.

LECTURE 3: THE INSECT HEAD

Objectives

At the end of this lecture you should be able to:

• Draw and label the various regions of a typical insect head.
• List important organs and parts found on the insect head.
• Name with specific examples the different orientations of insect heads.
• Relate the different head orientations to the mode of life of particular insect groups.

3.1: Introduction

• In the last lecture we studied the exoskeleton as part of the external morphology of an insect. In this lecture we will examine the insect head in more detail as part of the insect external morphology. We will continue studying the exoskeleton because it covers the insect head as well.
• We will also learn that insect heads have different types of orientations with respect to the rest of the body.

3.2: The Insect head

• Fig. 3.4: A typical insect head: frontal view

3.3: Orientation of insect heads

The various types of insect heads are an adaptation to different modes of life and habitats.

The types of orientations are indicated below

1. Hypognathous. This is the orientation in which the mouthparts are in continuous series with legs. It occurs mainly in phytophagous insects such as the grasshopper shown below. It is probably the most primitive evolutionarily.
2. Prognathous. This is the type of orientation whereby the mouthparts point forwards from the insect head. It occurs mainly in predaceous and carnivorous insects such as the beetle larva shown below.

3. Opistognathous, e.g. Aphid as shown on the figure below. In this type, the orientation of the head is such that the mouthparts are elongated and slope backwards between the front legs. It occurs in insects that insert their mouthparts into plant tissues, particularly among members of the orders Hemiptera and Homoptera.

3.4. Grooves and areas of an insect head

3.4.1: The Frons

The upper-mid portion of an insect's face is called the 'frons'.

The 'frons' is that area of the face below the top two 'ocelli' and above the 'frontoclypeal sulcus' (if and when this is visible) and in between the two 'frontogenal sulci', it supports the 'pharyngeal dilator' muscles and in immature forms it bears the lower two arms of the ecdysial cleavage.

3.4.2: The vertex

The rest of the front of the head: that bit which is above the frons is known as the 'vertex'. Vertex is the dorsal part of the frons.

3.4.3: The Clypeus

The 'clypeus' is that area of the face immediately below the frons (with which it may be fused in the absence of the frontoclypeal sulcus) and the frontoclypeal sulcus. It is the face of an insect. It supports the 'cibarial dilator' muscles and may be divided horizontally into a 'post.' and 'anteclypeus'. Below the clypeus is the labrum.

3.4.4: The Labrum

The 'labrum' is equivalent to the insect's upper lip and is generally moveable, it articulates with the clypeus by means of the 'clypeolabral suture'. On either sides of the clypeus are the edges of the 'mandibles'.

3.4.5: The Gena

The sides of the head are known as the 'gena'. Gena is the lateral area of the head beneath eyes. The subgenal sulcus divides into two, subgena below and postgena above. The gena is equivalent to the cheek.
## ACTIVITY 3.3

Match the words in column A to those in column B by inserting serial numbers preceding words in column A inside bracketed spaces in column B.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Vertex</td>
<td>a. Insect upper lip( )</td>
</tr>
<tr>
<td>2 Clypeus</td>
<td>b. Hypognathous head( )</td>
</tr>
<tr>
<td>3 Beetle larvae</td>
<td>c. Opistognathous head()</td>
</tr>
<tr>
<td>4 Gena</td>
<td>d. Top of insect head( )</td>
</tr>
<tr>
<td>5 Grasshopper</td>
<td>e. Prognathous head( )</td>
</tr>
<tr>
<td>6 Aphid</td>
<td>f. Upper mid portion of insect head( )</td>
</tr>
<tr>
<td>7 Frons</td>
<td>g. Cheek( )</td>
</tr>
<tr>
<td>8 Labrum</td>
<td>h. Simple eyes( )</td>
</tr>
<tr>
<td>9 Ocelli</td>
<td>i. area below the frons( )</td>
</tr>
<tr>
<td>10 sulcus</td>
<td>j. Plates( )</td>
</tr>
<tr>
<td>11 Sclerite</td>
<td>k. Antennae( )</td>
</tr>
<tr>
<td>12 Sensory</td>
<td>l. Lines( )</td>
</tr>
</tbody>
</table>

## ACTIVITY 3.2

This is a practical exercise. Check your own illustration against figures 3.1, 3.2, and 3.3 above.

Collect insects from vegetation, water bodies, soil and off animals nearby. Observe the orientation of the head in relation to the rest of the body. Sketch the head and indicate the type of orientation and the possible type of diet of your specimen.

### LECTURE 4: INSECT ANTENNAE

Antennae are sensory structures to help the insect find out more about its surroundings.

Except in the Order Protura, all insects' possess a pair of antennae.

The antennae are the insect's primary, non-visual, sense organs. Antennae come in a wide variety of shapes and sizes. This wide variation of insect antennae has adaptive advantage in that it enables the insect to be sensitive to a wide range of environmental conditions. The insect antenna is also of taxonomic importance in that it can be used to distinguish and classify different insect groups.

### 4.1: Introduction

In the last lecture we encountered the insect antenna as one of the most important structures on the insect head.

In this lecture you will study the insect antenna beginning with how its basic parts. You will then examine the different forms and sizes of antennae found in various insect groups.
ACTIVITY 4.1
Collect insects from vegetation, water bodies, soil and off animals nearby. Observe the orientation of the head in relation to the rest of the body. Sketch the head and indicate the type of orientation and the possible type of diet of your specimen.

4.2: Typical insect antennal structure

The parts of a typical insect antenna are described below:

**Basal Scape.** This structure is inserted into a membranous region of the head wall. The pivot is a single marginal point called *antennifer*. This arrangement enables the antenna to move in all directions. Generally the first segment of the antenna is known as the 'scape'.

**Pedicel.** The second segment second after the basal scape is called the as the 'pedicel'. This is a very short structure. It usually contains a special sensory organ called *Organ of Johnson*.

In two orders (Diplura and Collembola) the antennae lack a 'Johnston's organ' and all but the last segment contains intrinsic muscles, thus allowing far greater controlled movement of the antennae as is demonstrated by the rolling and unrolling of the antennae observed in the Collembola, *Tomocerus longicornus*.

**Flagellum.** After the pedicel, the rest of the antennae are the flagellum. It is divided into several annuli. The annuli are similar and joined by membrane so that the whole antenna is flexible. Annuli are not equivalent to segments, for example of legs. However, annuli of Collembola and Diplura (primitive orders) are true segments. This is because each has an intrinsic musculature in addition to unifying external muscles.

**Meriston:** This meriston is the proximal annulus, which divides to give to other annuli. In segmented antennae of Collembola and Diplura, antennal growth is apical.

The typical insect antenna is illustrated in figure 4.1 below:

![Fig. 4.1: A typical insect antenna](image)

ACTIVITY 4.2

1. List five parts of a typical insect antenna

4.3: Antennal variety

The structure of some antennae, such as the cockchafer, moth and mosquito are adapted in different ways to increase the surface area for sensory cells. The bee’s antennae have a simpler, more robust shape.

There is a great variety of form among insect antennae. Antennae of larval homometabolous insects are usually considerably reduced. Antennae of larval Neuroptera and Megaloptera contain a number of annuli. But antennae of larval Coleoptera and Lepidoptera are reduced to 3 simple segments. Finally, in some larval Diptera and Hymenoptera, antennae are very small and may be more than swelling.
of head wall. Since antennae are often used as aids in the identification of insects, knowledge of the common forms will be useful. Study the antennae exhibited by the following selected insects and label the drawings as to the type of antennae.

**TYPE DESCRIPTION FOUND ON**
- **SETECOUS** Bristle like Cicada/Dragon fly
- **MONOLIFORM** String of beads Rove beetle
- **SERRATE** Saw toothed Flat headed borer
- **FILIFORM** Thread like Field cricket/ground beetle
- **CLAVATE** Tapering club like Darkling beetle/ladybird beetle
- **CAPITATE** With a distinct head Nautili beetle
- **LAMELLATE** Tip with large, flat plates June beetle
- **PLUMOSE** With many plumes Male mosquito/Cecelia moth
- **PILOSE** With few plumes Female mosquito
- **ANNELATE** With rings Horse fly
- **ARISTATE** With an aristae House fly/Vinegar flies
- **GENICULATE** Elbowed Honey bee/Weevils
- **PECTINATE** Feather like Male Bombyx

**ACTIVITY 4.3**
Below are eight illustrations of different types of insect antennae. Copy each illustration in your laboratory notebook. Describe each type of antenna and give the common name of an insect in which each type of antenna is found on. Hand in this work to the course lecturer.
4.3.1: Sexual dimorphism in relation to insect antennae

In some insects antennae of the male is different from that of the female a phenomenon known as sexual dimorphism. Antennae of the male insects are usually more complex than those of females although in some species it is the reverse. It is quite usual that the males of a species have more elaborate antennae than the females; this is because it is normally the males who have to find the females.

The more elaborate the antennae the greater the surface area of the antennae. Antennae with larger surface area are more sensitive and can detect the more dilute scents, thus male insects with feathery antennae, such as those seen in many moths, are far more sensitive than the purely filamentous ones of crickets and cockroaches.

4.3.2: Significance of insect antennal variation

Insect antennae are useful in identifying insects. This is of great importance when we want to differentiate the vectors and plant pests from other insects, which are not harmful. In some insect groups such as mosquitoes it is only one sex, the female that sucks blood. In such cases if the male and female antennae are different, they can be used as a simple tool of differentiating males from females.

ACTIVITY 4.4

List six different types of insect antennae

4.4: Functions of the insect antennae

The various ways in which insects use the antenna are stated in the sections below

4.4.1: Antennae as sensory structures

The variations found in insect antennae are for serving precise functions. Basically, antennae are sense organs. They carry special organs called sensilla. These are often concentrated in particular areas. Their arrangement can be used for classification of species.

In most insects the antennae possesses a mechanosensory organ on the pedicel (the second antennal segment) called ‘Johnston's organ’ and, normally, only the basal antennal segment contains intrinsic muscles.

Various antennal sensilla function as follows:

1. Contact (tactile or mechanoreceptors)
2. Smell (odor receptors)
3. Chemical (chemoreceptors)
4. Gravity (hygrometers)
5. Pressure (proprioceptors)
6. Temperature (thermoreceptors)

However, sometimes insect antennae are used for other functions. Other functions of the insect antennae are stated in sections below:

4.4.2: Antennae as mating structure

Some male insects use the antennae to hold females during mating (i.e. the males of Meloe sp. {Coleoptera})
Fleas and Collembola also use antennae for mating purposes.

4.4.3: Antennae as organs for seizing prey

In a few rare instances antennae have become adapted for other purposes such as seizing prey items (i.e. the larva of Chaoborus sp {Diptera})

4.4.4: Antennae as respiratory structures

In the adult water beetle terminal annuli of the antennae are clothed with hydrofuge hairs. They facilitate formation of air bubble with which the insect submerges for respiration. You shall learn more about insect respiration in lecture 12.

ACTIVITY 4.5
Draw eight different types of insect antennae. Describe each type of antenna and give the common name of an insect in which each type of antenna is found on. Hand in this work to the course lecturer.

LECTURE 5: INSECT MOUTHPARTS

Objectives

Having studied this lecture you should be able to:

- Mention the two major types of insect mouthparts
- Draw the basic chewing mouthparts of a grasshopper
- List insects with either chewing or sucking mouthparts
- Discuss how the basic chewing mouthpart has been modified in the housefly and the honeybee.
- Describe the eight different sucking mouthparts found in insects such as thrips, plant bugs, mosquitoes, robber flies, stable and housefly, tsetse flies, fleas, lice and butterflies.

5.1: Introduction

- In the previous section we learnt about one of the head appendages; the antennae. In this lecture we are still studying the insect head but we shall consider a different head appendage; the mouthparts. We shall define two major types of insect mouthparts; the chewing and sucking mouthparts. You will observe how the basic chewing insect mouthpart has been modified for different feeding habits. In the first section of your lesson you will study the grasshopper mouthpart as a representative of the basic chewing mouthpart. The next item you will study is the modified chewing mouthpart found in other insects like honeybees. The final section of the lecture is an illustration of eight different types of sucking mouthparts.

You will require a hand lens and a pair of scissors or a razor blade to dissect the grasshopper mouthpart

5.2: Mandibulate or chewing mouthparts

No groups of arthropods present a greater diversity of mouthparts than insects. Generally, however, insect mouthparts are two types:

1. Mandibulate (Chewing) type.
2. Haustellate (Sucking) type.
• The chewing type is the more evolutionarily primitive. It occurs in adult Thysanura, Odonata, Plecoptera, Isoptera, Neuroptera, Mecoptera, Trichoptera, Colaeoptera and Hymenoptera. They considerably vary between these different insect groups.
• The most generalized condition of the mandibulate mouthparts type is found in the grasshoppers, locusts and crickets. The various mouth-part structures are most easily seen and studied by removing them from the insect one at a time and studying them under a lens or microscope. They consist of 5 parts listed below:
  1. Mandibles
  2. Maxillae) Major parts
  3. Labium
  4. Labrum) Minor Parts
  5. Hypopharynx

**Mandible**: They are paired, short strong, heavily sclerotized, unsegmented jaws. They lie immediately behind the labrum. They articulate with the head capsule at 2 points, one at anterior and one at posterior and move laterally. Biting surface is differentiated into distal incisor region and proximal moral region. Modifications are found in predaceous beetles where the mandibles are long and sickle like.

**Maxillae**: They are paired structures lying behind the mandibles. They are segmented, and each maxilla bears a feeler like organ the palp. The basal segment of the maxilla is the cardo, the second segment is the stipes. The palp is borne on a lobe of the strips called palprifer. The stipes bears at its apex 2 lobe like structures and the gelea, a lobe like structure. Variations in the maxillae in different chewing insects involve chiefly the palps and the terminal lobes. The palps are sensory organs. They test the quality of food. The terminal lobes are used to clean antennae, palps and front legs.

**Labrum**: This is the upper lip. It is broad flap like lobe situated below the clypeus on the anterior side of the head, in front of the other mouthpart structures. On the ventral or posterior side of the labrum is a swollen area, the epipharynx.

**Hypopharynx**: This is a short tongue-like structure, which can easily be seen if the mandible and maxilla on one side are removed. It is located immediately in front of or above the labium and between the maxillae. In most insects the ducts from the salivary glands open on or near the hypopharynx. Mostly membranous in structure, but the dorsal surface is sclerotised distally. Proximally it contains a pair of sensory sclerites. In Apterygota, larval Ephemeroptera and Demaptera there are two lateral lobes of he hypopharynx called superliguae.

**Labium**: This is the lower lip. Structurally, similar to maxillae, but appendages of the two sides are fused together to form a single structure. It is divided by a transverse suture, into portions, a basal postmentum and a distal prementum. The postmentum in the grasshopper locust or cricket is divided into a basal submentum and a distal mentum.
The prementum bears a pair of palps and group of apical lobes which form the ligula, consisting of a pair of small mesal lobes, the glossae, and a pair of larger lateral lobes, the para-glossae, the labial palps are borne on lateral lobes of the prementum, called palpigers. All the muscles of the labium have their insertion distal of the labial suture. The variations in labial structures in chewing insects involve primarily the structure of the ligula and the sclerotization of the basal portion of the labium. The prementum closes the preoral cavity from behind. The labial palps function like those of the maxillae.

5.3: Variations in insect mouthparts

From the simple generalized structures found in the mandibulate or chewing insect mouthparts several phylegetic lines have arisen through adaptations. These adaptations have occurred to enable puncturing plant and animal tissues and (ii) also for sucking juices. Other adaptations are for drinking nectar from flowers. Still other insects have evolved defensive adaptations not directly concerned with feeding. Some of these adaptations are as follows:

Insect mouthparts have evolved for chewing (beetles, caterpillars), piercing-sucking (aphids, bugs), sponging (flies), sucking (moths and butterflies), rasping-sucking (thrips), cutting-sponging (biting flies), and chewing-lapping (bees and wasps).

Mouthparts of moths and butterflies are adapted to form a galea for sucking liquid food such as nectar from flowers and when the insect is not feeding the long feeding tube is coiled.

Piercing and sucking mouthparts are found in herbivorous insects such as aphids, leaf hoppers, which feed on plant juices.

In biting flies such as horseflies the mouthparts function as knife-like mandibles, to produce the wound. Blood is then collected from the wound by a sponge-like labium and conveyed to the mouth by a tube formed from the hypopharynx and epipharynx.

Some predatory flies and Hemiptera inject salivary secretions into the prey and suck up already digested tissues.

Certain non-biting flies such as houseflies use a sponge-like labium a lone for obtaining food, the mandibles and maxillae being reduced. Insects such as the houseflies are not limited to liquid food. Saliva can be exuded through the labium to liquify the solid food and the fluid sucked back into the mouth. Such mouthparts are referred to as sponging mouthparts.

Assassin bugs and mosquitoes, which feed on fluids of other animals, have specialized needle-like mouthparts that form a stylet.

ACTIVITY 5.1

Tabulate the various components found in a basic chewing mouthpart of an insect

5.3.1: Combination (Chewing-sucking) mouthparts

Bees and wasps have mouthparts sometimes referred to as combination mouthparts. Mouthparts are modified to utilize liquid food, honey and nectar. A central "tongue" is used to draw liquid into the body. The mandibles are not used for feeding but function to cut floral tissue to gain access to nectar, for defense, and for manipulating wax.
This means that the mouthpart is a combination of both chewing and sucking. The bee mouthparts are greatly elongated. The labium and maxillae are modified into a tongue like structure through which liquid food is sucked. Fused glossae form a long, slender flexible tongue. This, together with small paraglossae, can be partly retracted into prementum. Labial palps are as long as the tongue and flattened. The geleae are also elongated and flat. The maxillary palps are vestigial pegs and the lacinae are entirely absent. The mandibles are spatulate or spoon-shaped but not used for feeding. They are instead used for nest construction, e.g. to work the wax and fashion the hexagonal cells in the honeybee. To feed, the bees form a proboscis by bringing the flat galeae and labial palps together over the tongue. Movements of the tongue within the proboscis bring liquid to the mouth. It is then sucked in by the pumping action of he muscles around the buccal cavity and pharynx. In bees the nectar is gathered by the elongate maxillae and labium while the labrum and mandibles handle pollen and wax, which have retained the chewing form. Modifications of the tongue provide useful taxonomic characters in separating bee species.

Combination mouthparts are also found in larvae of some Neuroptera e.g. ant lions, and larvae of predaceous diving beetles. The larvae of some Neuroptera, e.g. ant lions, owl flies, have the mandibles and maxillae elongated, and suck up the body fluids of their prey through a channel between the mandibles and maxillae. The larvae of predaceous diving beetles suck the body fluids of their prey through channels in the mandibles.

**Chewing-Lapping** - Bees and wasps have mouthparts sometimes referred to as combination mouthparts. Mouthparts are modified to utilize liquid food, honey and nectar. A central "tongue" is used to draw liquid into the body. The mandibles are not used for feeding but function to cut floral tissue to gain access to nectar, for defense, and for manipulating wax.

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**ACTIVITY 5.2**

- State two insects with a combination mouthpart
- What role do mandibles play in the bee mouthpart?
- What part of the bee mouthparts gathers nectar and pollen respectively
- Are there parts that are vestigial in relation to bee mouthparts?
- Name the part that is entirely absent from the bee mouthpart.
5.4: Haustellate or sucking mouthparts

**Haustellate or Piercing-Sucking** mouthparts are found in a variety of insects, such as herbivorous and predacious bugs and mosquitoes. Mandibles and maxillae are formed into stylets, which are enclosed by the labium. Once the stylets penetrate, a secretion is injected to dissolve tissue, act as a toxin in predacious species, or as anticoagulant for mosquitoes.

Insects with haustellate mouthparts have them in the form of elongated proboscis or beak. Through it liquid food is sucked. The mandibles are either elongate and style like or are lacking. Like in the mandibulate insects, haustellate mouthparts have undergone considerable variation in different insects. There are eight principal variations as follows

5.4.1: Thrips type

The proboscis is a short, stout, asymmetrical, conical structure. It is located ventrally in the rear of the head. The labrum forms the front of the proboscis; the basal portions of the maxillae form the sides. The labium forms the rear.

There are 3 styles: the left mandible (the right mandible is rudimentary), and 2 maxillary stylets. Both maxillary and labial palps are present, but short. The hypopharynx is a small medium lobe in the proboscis. The mouthparts of thrips have been termed "rasping-sucking". However, it is probable that the stylets piece rather than rasp the tissues fed upon. The food ingested is generally in liquid form, but very minute spores are sometimes ingested.

5.4.2: Hemiptera (Bug) Type

This is found in Hemiptera and Homoptera. The beak or rostrum or proboscis is elongate, usually segmented and arises from the front (Hemiptera) of the head. It is carried under the body between the legs.

The external segmented structure of the beak is the labium. It is sheath like and encloses 4 piercing stylets.

The 2 mandibles

The 2 maxillae

The labrum is a short lobe at the base of the beak on the anterior side. The hypopharynx is a short lobe within the base of the beak.

The labium does not piercing, but folds up as the stylets penetrates the plant tissues. The inner styles in the beak, the maxillae and mandibles are structured in such a way as to form 2 channels, a food channel and a salivary channel. It is divided into section. The palps are absent.

5.4.3: The lower Diptera (Mosquito) Type

These are found in the biting lower Diptera comprising sand flies, culicids and the mosquitoes, these insects have 6 piercing stylets: the labium, the paired mandibles, the paired maxillae and the hypopharynx enclosed within a grooved of the labium.

The stylets may be very slender and needlelike (mosquitoes) or broader and knifelike (the other groups). The maxillary palps are well developed, but labial palps are lacking (some Dipterists regard the labella lobes as labial palps). The salivary channel is in the hypopharynx and the food channel is between the grooved labrum and the hypopharynx (for e.g. mosquitoes), or between the labrum and the mandibles (for e.g. Culicoides and the horse flies. The labium does no piercing and folds up or back as the stylets enter the tissue being pierced.
5.4.4: The Robber Fly (Asilidae) Type

In these insects, the mouthparts are similar to those of the piercing group, but there are no mandibles. The principal piercing organ is the hypopharynx.

There are 4 styles: the labrum, the paired maxillae and the hypopharynx. The food channel is between the labrum and the hypopharynx. The robber flies feed on other insects or spiders, and only rarely bite man.

5.4.5: The Higher Diptera (Cyclorrhapha) Type

By "higher" Diptera comprises of flies that belong to the suborder Cyclorrhapha. The mandibles in these flies lack palps. The maxillae are represented by maxillary palps. The proboscis consists of the labrum, hypopharynx and labium. There are 2 modifications of the mouthparts in these flies.

(a) a piercing (Hippoboscidae) type, and

(b) a sponging or lapping type.

(a) Piercing (Hippoboscidae) Type:

The higher Diptera with piercing mouthparts include the stable fly, tsetse fly, horn and the louse fly (Hippoboscidae). The principal piercing structure in these flies is the labrum.

The labrum and hypopharynx are slender and stylet-like, and lie in a dorsal groove of the labium. The later terminates in a pair of small hard plates, the labella. There may be sharp teeth on the pseudotracheae to rasp flesh and draw up blood. The labella is the fleshy distal end of the labium that functions as a sponge-like organ to sop up liquids.

These are armed with teeth the salivary channel is between the labrum and hypopharynx. The proboscis is the horse flies is somewhat retracted into a proud on the ventral side of the head when not in use.
Sponging - Found in adults of specialized flies. During feeding the proboscis (modified labium) is lowered and salivary secretions are pumped onto the food. The dissolved or suspended food then moves by capillary action into the pseudotracheae (spoon) and is ingested. There may be sharp teeth on the pseudotracheae to rasp flesh and draw up blood. The labella is the fleshy distal end of the labium that functions as a sponge-like organ to suck up liquids.

The labrum and hypopharynx are slender and lie in an anterior groove of the labium. The labium forms the bulk of the haustellum. The salivary channel is in the hypopharynx. The food channel lies between the labrum and the hypopharynx. At the apex of the labium are the labella a pair of large, soft oval lobes. The lower surface of these lobes bears numerous transverse grooves, which serve as food channels. The proboscis can usually be folded up against the lower side of the head or into a cavity on the lower side of the head. These flies lap up liquid food. This food may be already in liquid form, or it may first be liquidified by salivary secretions of the fly.

5.4.6: Flea (Siphonaptera) Type

These mouthpart types are similar to those of the mosquito but without mandibles. Adult fleas feed on blood. Their mouthparts contain 3 piercing styliets. The epipharynx and the laciniae of the maxillae. The labrum is a very small lobe on the upper surface of the head. It lies in front of the base of the head.

It is the epipharyngeal of the labrum that is elongated into piercing styliets. The maxillae consist of large plates or lobes. Each bears a piercing lacinia and a large palp.

The labium is short and slender. It bears short palps, the labium and its palps serve to guide the styliets. The hypopharynx is a small lobe like structure. It lies within the base of the beak.

The food channel is found between the epipharynx and the maxillary styliets. The salivary channel lies between the edges of each maxillary styliets.

5.4.7: The Sucking Lice (Anoplura) Type

The mouthparts of these insects are highly specialized. Therefore they are different to homologise with those of other sucking insects. There is a short rostrum. This is probably the labrum. It occurs at the anterior end of the head. From this structure 3 piercing styliets arise. The rostrum is eversible and it is armed internally with small recurved teeth.
The stylets are about as long as the head. When not in use, they are withdrawn into a long saclike structure lying below the alimentary canal. The dorsal stylet probably represents the fused maxillae. Its edges are curved upward and inward to form a tube. This tube serves as a food channel. The intermediate stylet is probably the hypopharynx. It is very slender and contains the salivary channel. The ventral stylet is probably the labium. It is the principal piercing organ. It is a trough-shaped structure. There are no palps.

5.4.8: The Lepidopteron (Butterfly) Type

Siphoning - found in moths and butterflies. When feeding the proboscis is uncoiled and extended. Nectar is sucked up into the mouth or oral cavity. The proboscis is a modified maxillae.

In these mouthparts type, the proboscis is formed from the 2 maxillary galeae. These are enormously elongated with a medium groove. This groove forms a tube between the galeae when they are pressed together, forming the food channel. The two elements are held together by interlocking hooks and spines.

Galea are annulated externally and are very flexible. The labrum is reduced to a narrow transverse band across the lower margin on the face. The mandibles and hypopharynx are present in the adult. The maxillary palps are usually vestigial or absent. The cardo and stipes are reduced. The labium is usually represented by a small plate with usually well-developed labial palps. There is no special salivary channel.

This type of mouthparts structure is sometimes called siphoning-sucking. This is because there is no piercing. The insect merely sucks or siphons liquid up through the proboscis. When in use, the proboscis is uncoiled by blood pressure, it recoils by its elasticity.

5.5: Orientation of insect mouthparts

In a previous lecture we learnt that the insect head had three different types of orientations in relation to the rest of the body. Similarly, the insect mouthpart is oriented in different ways in relation to the head. The two different types of mouthpart orientations are stated below:

5.5.1: Ectognathous mouthparts

When mouthparts are visible and exteriorly situated they are known as ectognathous. Flies, fleas, grasshoppers and butterflies are examples of ectognathous conditions.

5.5.2: Endognathous mouthparts

Endognathous mouthparts are enclosed within the head. Collembola and sucking-lice have this kind of mouthparts. Endognathous situation results from two conditions:

- Enclosed by skeletal flaps that grow around them, e.g. Collembola.
- Enclosed by the process of invagination e.g. in Anoplura (sucking lice). They are also called crytognathous.

5.6: Vestigial mouthparts

A few adult insects have non-functional vestigial mouthparts. These insects cannot feed and have a very short adult life spans. Vestigial mouthparts are found in may flies.
In this lecture we have learnt that:

- The two major insect mouthparts are the chewing and the sucking types.
- The grasshopper mouthpart can be representative of the typical chewing insect mouthpart.
- The basic chewing mouthpart is composed of the mandibles, the maxillae, the labium, the labrum and a tongue-like hypopharynx.
- The chewing mouthpart has been modified in various insect groups to suit different types of feeding modes.
- Some insects such as the honey bee have a combination mouthpart suited for both chewing and sucking.
- The butterfly mouthpart has been modified to form an extremely elongate tube suited for sucking plant juices.
- Mouthparts of blood-sucking insects such as mosquitoes have stylets which are needle-like projections suited for piercing tissues of man and animals to draw a blood meal.
- Mouthparts of house flies are described as lapping or sponging and can lap liquid food. Such flies can also liquefy their food with salivary secretions before lapping the material.
- Some predatory insects inject salivary secretions into their prey before sucking up the liquefied tissues.
- Endognathous insect mouthparts such as those found in lice are enclosed within the head and are not visible when not in use.
- Ectognathous insect mouthparts are visible exteriorly. Such mouthparts are found in butterflies, grasshoppers, fleas and most flies.
- Some insects such as mayflies have nonfunctional vestigial mouthparts.

ACTIVITY 5.3

1. List eight different insects with different kinds of sucking mouthparts.
2. Explain the adaptive advantage insects derive from diverse types of mouthparts.
3. Compare and contrast the mouthpart of a butterfly with that of a grasshopper.
4. Describe with specific examples, endognathous; ectognathous and vestigial mouthparts.
5. Name six insect orders with chewing mouthparts.

LECTURE 6: THE INSECT NECK, THORAX AND LEGS

Objectives

Upon completion of lessons in this lecture you should be able to:

- Briefly describe the insect neck.
- Name the main plates (sclerites) found in the thorax.
- List the three segments of the insect thorax.
- Illustrate the typical insect leg.
- Discuss different types of the insect leg including a running, jumping, grasping, digging, swimming and pollen carrying legs.
- Mention other functions of insect legs other than movement.

6.1: Introduction
In the last lectures we have been studying the head and its appendages. In this lecture, we will move to the neck and thorax. We shall learn the basic plates of the exoskeleton within the thorax. Next, we shall note that within the thorax there are the legs and the wings, both of which are important locomotory apparatus for insects. The insect legs will be examined in this lecture while the wings will be studied in the following lecture.

After you have studied a typical insect leg, you will consider insect legs that have been modified to suit various modes of insect life.

In order to be able to see the basic components of the insect leg, you will require a hand lens, a pair of scissors or a sharp razor blade. You will also require either a cockroach or grasshopper.

6.2: The neck

The neck or cervix of an insect is a membranous region. It links the head to the thorax. Probably it represents the posterior part of the labial segment. Laterally in the neck membrane are the cervical sclerites. Typically, there are 2 on each side. Running through to the head are longitudinal muscles, dorsal muscles and ventral muscles. They serve to retract the head on the prothorax. Their differential contraction cause lateral head movements.

6.3: The insect thorax

The thorax of an insect is the middle region of the body. It consists of 3 segments: the prothorax, mesothorax and metathorax. In most insects all 3 segments bear a pair of legs each. Exceptions are larval Diptera, larval Hymenoptera, some larval Coleoptera and small number of adults. In addition, winged insects have a pair of wings on the meso and metathorax. For this reason, these 2 segments are collectively called pterothorax. Each thoracic segment is composed of a number of sclerites.

The entire arrangement of thoracic sclerites is for muscle attachment and provision of rigidity to thorax. Any of these sclerites may be identified on a particular segment by using the appropriate prefix, either pro-, meso- or meta-.

For example, the notum of the prothorax is called the pronotum. In grasshoppers, locusts and crickets, this structure is a conspicuous saddle-like plate between the head and the base of the wings. The nota of the mesothorax are often divided by sutures into 2 or more sclerites each. In winged insects, there are 2 principal notal sclerites: the alinotum and the postnotum. The former occupies most of the notum. The alinotum is divided into two (2) sclerites, an anterior scutum and a posterior scutellum. In some insects, there are additional sutures on the alinotum.

Each pleuron is divided into 2 sclerites by a pleural suture. The suture extends dorsoventrally between the base of the leg and the base of the wing. The anterior sclerite is the episternum, and posterior sclerite is the epimeron.

In a wing-bearing segment, the pleuron is produced into a pleural wing process at the upper end of the pleural suture. This process serves as fulcrum for the movement of the wing. There are usually one or two small sclerites, the epipleurites, in the membranous area between the pleuron and the base of the wing. These are important to the wing movements. Certain muscles that move the wing are attached to these sclerites.

Each sternum may be divided into 2 or more sclerites. The spiracles are slit-like openings, one between the prothorax and the other one between the mesothorax and metathorax, on each side of the thorax. These are the external openings of the respiratory system.
ACTIVITY 6.1

1. How many segments are in an insect thorax? Name them

2. Name the sclerites found in the following areas of the insect thorax: dorsal side, ventral side and lateral side

3. Describe the position of the spiracles in relation to the insect thorax

6.4: The typical insect leg

As it has already been noted, with a few exceptions, all insects have 3 pairs of legs. Each leg consists typically of 6 elements or segments: the coxa, the basal segment, the trochanter, a small segment following the coxa, the femur, the 1st long segment of the leg; the tibia, the second long segment of the leg, the tarsus, a series of small segments beyond the tibia, the first of which is post-tarsus consisting of the tarsal claws and other structures, at the end of the tarsus.

The coxa bears articulation with thorax. It is strengthened by a ridge called basicoxite. The trochanter is small and can only move vertically. Rarely in some insects (Odonata) may the trochanter be 2-segmented. They are immovable and fixed on each other. The femur is the largest leg segment in most insects. It is fixed on the trochanter without muscles to move it. The tibia is the long slender shank of the leg. It is joined with the femur in a way permitting the 2 segments to be drawn close together into a nearly parallel position.

The tarsus, in most insects, is subdivided into 1-5 tarsomeres, these subdivisions of the tarsus, do not have muscles of their own. Therefore, they are not true leg segments. Hence they are called sub segments or tarsomeres. The number of the tarsomeres in different insects is important for classification. The basal tarsomere is called the metatarsus. It articulates with the tibia. The rest have no articulation. The proximal tarsomere is the post tarsus. Muscles that move the tarsus come from the tibia to the metatarsus. In Protura and Collembola, the tarsus, is a single segment.

The post tarsus or pretarsus in Protura and Collembola is a single claw-like segment. In most insects, it consists of 4 elements:

1. A membranous base with a median lobe, the arolium.

2. A pair of claws articulating with a medium process of the last tarsomere known as the unguifer.

3. Ventrally is a basal sclerotised plate, the unguitractor.

4. Between this unguitractor and claws are small plates called auxillae.

In Diptera, a membranous pulvillus arises from the base of each auxillium. It may be a spine or lobe-like. Claws may or may not be equal in size.

The typical insect leg is illustrated below in figure 6.1:

Figure 6.1: A typical insect leg
ACTIVITY 6.2 Answers are in the text

1. Diagrammatically illustrate the structure of a typical insect leg

2. State the significance of tarsomeres of the insect leg

3. Name the four elements of post tarsus

6.5: Various types of insect legs and their functions

The insect legs may be variously modified in different insects. The various characters provided as a result of these modifications are of considerable importance in identification. The different segments of the leg may vary in size, shape or spination. For example as we have already seen, the number of tarsal segments varies in different insects. Some of the adaptations of locomotory legs in insects are described below;

1. Jumping or leaping leg

The hind leg of the grasshopper and locusts produces the leap when suddenly extended. Most of the power comes from the hind legs

2. Running or crawling leg

This kind of leg is illustrated below and is found in insects such as cockroaches

3. Swimming leg
Larval and pupal Diptera, larval and adult Heteroptera and Coleoptera form the bulk of free-swimming insects and most of these use the hind legs and or the middle legs, in swimming. The hind tibiae and tarsi are greatly flattened to form an oar or paddle, which is greatly increased in surface area by inflexible hairs as in Gyrinus (Coleoptera). As shown on figure 6.5 above.

The hind leg of the hydrophilic beetle is provided with a fringe of (setae) which serve as oar for swimming. An unusual adaptation is found in the Geriddae, water striders. They belong to the order Hemiptera. The lightness of these on the middle tarsi, enable them to skim along on the water without breaking through the surface film.

4. Raptorial or grasping leg

For grasping prey, the fore leg of the praying mantis is equipped with a formidable array of spines along the opposing edges of the femur and tibia. A different device for grasping prey is found on the foreleg of the predaceous water bug Naucoria (Hemiptera). In this insect the tarsus is formed as a single sharply pointed segment. The bird louse (Mallophaga) closes the post-tarsal spur around a father of its host and clings the post-tarsal spur around a father of its host and clings there. The crab louse (Anoplura) achieves the same end with the claw-like modifications of its tibia and tarsus.

5. Digging leg

The digging fore leg of the mole cricket (Orthoptera) is one of the most striking adaptation of all. Short and strong, it is tipped by a hand-like arrangement of tibia and tarsus. Phasmids (Stick-insects) of the tropical family Phyllidae are dramatically adapted in shape and coloration to stimulate foliage. The femora and tibia have leaf-like expansions to contribute to the illusion.
ACTIVITY 6.3

Fill in the blanks in the following sentences

1. The pollen basket found in the fore tibiae of Hymenoptera is called
   a.

2. Water striders have legs (digging, crawling, swimming)

3. Insects have pairs of legs.

4. The large conspicuous saddle like plate between the insect head and the base
   of the wings is called (prota, pleura, pronotum)

5. The trochanter is two-segmented in (Diptera, Odonata)

6. The large terminal spur on the fore tibiae of Hymenoptera is called
   (coxa, calcar, radius)

6.5.1: pollen carrying leg

The front legs have clusters of hairs that the worker bee uses to brush pollen from her body to the "pollen baskets" or corbicula that are on her back legs. The front legs have an extra joint and a comb that the bee uses to clean herself.

The middle legs are covered with stiff hairs that help the worker bee brush pollen back to the "pollen baskets" and remove pollen from the baskets upon return to the hive. The hind legs have "pollen baskets," or bare spots surrounded by stiff hairs. The hairs help hold the pollen in place. Nectar is often added to the pollen to make it clump. This makes it easier to transport in the baskets.

The antennae are drawn through this structure so that the fine hairs in the cavity remove pollen and other things clinging to them. Bees transport pollen to their hives by means of special equipment on the hind leg called the pollen basket or corbicula.

The pollen basket or corbicula is part of the tibia on the hind legs of honey bees. A honeybee moistens the forelegs with a protruding tongue and brushes the pollen that has collected on head, body and forward appendages to the hind legs. First, the pollen is transferred to the pollen comb on the hind legs and then combed, pressed, compacted, and transferred to the outside surface of the tibia of the hind legs. The enlarged 1st tarsal sub segment (basitarsus) of each hind leg has a row of stiff setae known as scopae or pollen comb. Pollen adheres to the hairy bodies and legs of bees. It is then transferred to the pollen basket. The pollen collected on the combs of one side is then removed by the rake of the opposite hind legs and collects in the pollen press. By closure of the press pollen is forced outwards and upwards onto the outside of the tibia and is then held in place by hairs and spines of the pollen basket. On returning to the hive, the pollen is kicked off by the middle legs into an empty cell.
6.6: Other functions of the insect leg

Other functions of the insect legs include sound production, silk production and hearing (auditory organ) as outlined below:

6.6.1: Sound production

Certain functions in addition to locomotion sometimes are performed by legs. These are functions that require special structures or special adaptations of existing structures. One such extra function is stridulation. However, stridulation does always involve the legs. When a leg is used for this purpose, it has a roughened area. When this area is drawn across a ridge or projection on some conveniently located part of the body, it produces sound. In the Acrididae (Orthoptera) the males and females of a few species produce a buzzing sound when the hind femur is drawn across an enlarged vein of the forewing. In this family, the inner surface of the hind femur is usually has a row of pegs on the wing and the femur has a longitudinal ridge.

6.6.2: Auditory organ

An "ear" may be present on the tibia of many Orthoptera. The flat tympanum is some times uncovered and easily seen. The internal organization of this auditory apparatus is complicated and involves modifications of both the nervous and tracheal systems. (We shall come back to it when discussing the nervous system). The cricket and long-horned grasshoppers have an eardrum or tympanum at the base of the front of the tibiae.

6.6.3: Gustatory

The tarsi of Diptera contain sensilla that can detect different food tastes.

6.6.4: Silk production

Some insects have silk glands in their fore tarsi sub segments. Their legs are used to spin this silk either into a living house like in the Embioptera. In the male Empididae, the silk is used to enclose other animals for food which is often offered to the female as part of the mating ritual, sort of a bridge to ensure her co-operation.

ACTIVITY 6.4

1. Describe five types of the insect legs.

2. Name three functions of an insect leg apart from being a locomotory apparatus.
3 State a unique feature of the honey bee leg.

LECTURE 7: INSECT WINGS

Objectives

At the end of this lecture you should be able to:

- Describe the typical structures of an insect wing
- Outline the system used in describing the insect wing veins and cells
- State the changes that the insect wing has undergone in the course of evolution
- Define and draw special kinds of wings such as elytra, tegmina, hemelytron, and halteres.
- Explain how insects use wings to produce sound.
- Understand that the success of the insects as terrestrial animals is at least partly due to their ability to fly.

7.1: Introduction

In the last lecture we discussed the insect legs within the thorax. The other thoracic appendage alongside the legs are the wings. In this lecture, we shall study the typical structure of an insect wing. We shall then progress to examine the more specialized insect wings found in beetles, stick insects, moths, thrips and lacewings. We shall note that some insects are wingless secondarily in that they have lost their wings in the course of evolution. In the last section of the lecture we shall observe that wings are used by insects to produce sound. A fossil insect wing will be mentioned in this lecture, find out its name!

In order to practically see the insect wing variations you will need a grasshopper, a housefly, a butterfly, a beetle, a praying mantis, a bedbug, a dragonfly, lacewing and an ant. Do not worry if you cannot get all these but try to get at least five of them. You will also require a hand lens.

7.2: The insect wing

All winged arthropods are insects, but not all insects have wings. The wings of insects are outgrowth of the body wall, which have been flattened. They are not modified appendages, as in birds and bats.

Most adult insects have two pairs of wings. The 1st pair is located on the mesothorax and the second on the metathorax. But some have only one pair. It is usually the mesothoracic pair. Flies and mosquitoes have one pair of wings. Wings can be prominent as in the lacewing and butterfly, or modified to be less obvious. The beetle’s front pair of wings provide a hard or leather-like covering that protects the back pair when they are not being used.

In most insects, the wings are membranous. In other words, they are like cellophane and may bear tiny hairs (microtrichia) or scales or spines (macrotrichia). In some insects the forewings are thickened, leathery or hard and sheath like. Some wings are semitransparent; the typical semi-transparent wing is found in Dragon flies, bees and wasps.

Most insects are able to fold their wings over the abdomen when at rest. But the dragonflies, damselflies and mayflies cannot do this. They hold their wings either outstretched or together above the body when at rest.

It is important to note that the success of the insects as terrestrial animals is at least partly due to their ability to fly.

Functional wings exist only during the adult stage of an insect’s life cycle. The wings develop embryologically as evaginations of the exoskeleton – they may be membranous, parchment-like, or heavily sclerotized. Most insects have two pairs of wings -- one pair on the mesothorax and one pair on the metathorax (never on the prothorax). Wings serve not only as organs of flight, but also may be adapted variously as protective covers (Coleoptera and Dermaptera), thermal collectors (Lepidoptera), gyroscopic stabilizers (Diptera), sound producers (Orthoptera), or visual cues for species recognition and sexual contact (Lepidoptera).
Using either a grasshopper or a dragonfly or both, carefully remove the fore and hind wings from the base. Lay each one on a flat surface preferably a glass surface. Make careful drawings of both the fore and hind wings. Try to identify the cells and veins described under section 7.2.3 above.

### 7.2.1: Typical insect wing structure and texture

Wings are located dorsolaterally between the nota and pleura of the meso- and metathoracic segments. They arise as saclike outgrowths. But in the adult insect they are solid structures. The only cavities in them are the veins. The solid structures consist of two closely united layers of integument. The layers are then strengthened by sclerotised veins. The Fully developed and functional wings occur only in adult insects.

### 7.2.2: Internal wing structure

Within each of the major veins is a nerve and trachea. Blood space is continuous with the rest of the body cavity, the haemocoel. Hence it is filled with blood circulating around the wing. Both the cuticle and the epidermis are continuations from the general body wall or integument of the insect.

### 7.2.3: Wing venation

#### Veins

Insect wings have venation, a system of thickened lines in the wing.

In most cases, a characteristic network of veins runs throughout the wing tissue. These veins are extensions of the body's circulatory system. They are filled with hemolymph and contain a tracheal tube and a nerve. In membranous wings, the veins provide strength and reinforcement during flight. Wing shape, texture, and venation are quite distinctive among the insect taxa and therefore highly useful as aids for identification. The number and arrangement of the veins is of great taxonomic value. For this reason, a system of terminology has been developed that is applicable to all insects. This is known as the Cosmstock (or Comstock-Needham) system, devised by John Comstock and George Needham.

The Comstock-Needham system recognizes eight major longitudinal veins, abbreviated by capital letters. Starting from the anterior margin of the wing they are: costa (C), subcosta (Sc), radius (R), medius (M), cubitus (Cu) and 3 anal (1A, 2A, 3A). The branches of the longitudinal veins are named from anterior to posterior around the wing.

#### Fusion of veins

Two veins may fuse for part or all of their length, appearing as one vein. The resulting vein takes the name of both component veins joined by a plus (+) sign. For example, Rs and M are often fused for portions of their lengths. The fused portion is called Rs+M. Veins may fuse end to end so that it is impossible to know exactly where the first one ends and the second begins. In these cases the composite veins are joined with an ampersand (&). For example, in all Ichneumonidae and many Braconidae the first abscissa of vein RS+M is often completely lost and in these cases veins 1RS and 1M cannot be distinguished from one another: the composite vein is therefore termed RS&M.

#### Crossveins

Names of cross veins are based on their position relative to longitudinal veins: Cross veins, indicated by lower case letters, take the name of the veins they connect, with the anterior vein given first. Thus, a cross vein that connects R with M is r-m. If there are several r-m cross veins they take numerical values as well e.g. 1r-m, 2r-m, etc. If a cross vein joins two branches of the same vein the cross vein takes the name of the major longitudinal vein, e.g. a cross vein between R1 and R2 is called r. This simplification is possible due to the rarity of this type of cross vein.

The cross veins are named accordingly to their location in the wing or the longitudinal veins they connect. The humeral cross veins (h) is located near the wing base, between the costa and the subcosta. The radial cross vein (r) connects R1 and the anterior branch of the radial sector. The sectorial cross vein (s) connects Rs and R2. The radio-medial cross vein (r-m) connects the posterior branch of the radius and the anterior branch of the anterior of the medial vein. The medial cross vein (m) connects M1 and M2. The medio-cubital cross veins (m-Cu) connects the posterior branch of the media and the anterior branch of the cubits. The cubitoanal cross vein (Cu-a) connects the posterior branch of the cubits and the and the first anal vein.
### Wing cells.

The spaces between the veins are called cells. Each cell is named using the name of veins forming the anterior and posterior boundary veins, e.g., the spaces between 2nd and 3rd medial branches are named either as "cell M₂" or cell M₁-M₃. Cells may also be designated by descriptive terms, indicating position. e.g., "distal cell", "marginal cell" and so on.

Wing cells, abbreviated with capital letters, take the name of the vein lying anterior to them. If several fused veins form the anterior boundary of a cell, the cell takes the name of the vein that is theoretically most posterior. Thus, the cell posterior to C+Sc+R is the radial cell (R). If more than one cell is directly behind a vein, the cells are numbered consecutively from the base of the wing, e.g., three medial cells would be 1M, 2M, and 3M.

#### 7.2.3.1: Key to major veins

- **Costa (C)** -- the leading edge of the wing
- **Subcosta (Sc)** -- second longitudinal vein (behind the costa), typically unbranched
- **Radius (R)** -- third longitudinal vein, one to five branches reach the wing margin
- **Media (M)** -- fourth longitudinal vein, one to four branches reach the wing margin
- **Cubitus (Cu)** -- fifth longitudinal vein, one to three branches reach the wing margin
- **Anal veins (A₁, A₂, A₃)** -- unbranched veins behind the cubitus

A vein may have several segments or abscissae. They are delimited by the intersection of other veins, usually crossveins. Thus a vein that is intersected by two other veins has three abscissae, numbered consecutively from the base to the apex of the wing, e.g., when Cu has three abscissae, they are 1Cu (the basal portion of Cu), 2Cu and 3Cu (the apical portion of Cu). Vein abscissae may vary interspecifically, therefore 3Cu of one species is not necessarily homologous with 3Cu of another.

The branches of the longitudinal veins are named from anterior to posterior around the wing. The two branches of the subcosta are designated sc₁ and sc₂. The radius (R) gives off a posterior branch the radial sector (Rs) usually near the wing's base. The anterior branch of the radius is R₁. The radial sector forks twice, with 4 branches reaching the wing margin. The cubitus, L (Cu₁) according to authorities, Cu₁ forks again distally, the two branches being Cu₁a and Cu₁b. According to some authorities, Cu₁a and Cu₁b. the anal veins are unbranched and are designated from anterior to posterior as the 1st anal (1A), 2nd anal (2A) and so on. forks again distally, the branches being Cu.

When a vein is branched the most anterior branch is given the subscript 1 and the more posterior branches the subscripts 2, 3,... This is done for all veins except R. When R branches the most anterior branch is called R₁ but the second branch is called the radial sector (RS).

An illustration of the main veins of an hypothetical primitive insect wing is shown below:

![Fig 7.1: Hypothetical primitive insect wing](image)

#### 7.3: The Archedictyon insect wing

The Archedictyon is the name given to a hypothetical scheme of wing venation proposed for the very first winged insect. It is based on a combination of speculation and fossil data. Since all winged insects are believed to have evolved from a common ancestor, the
Archedictyon represents the "template" that has been modified (and streamlined) by natural selection for 200 million years. According to current dogma, the Archedictyon contained 6-8 longitudinal veins.

Fossil insects show that the primitive insect wing had areas between longitudinal veins (cells) densely reticulated. Such a wing is known as the Archedictyon. The Archedictyon persists at the base of the forewings of grasshoppers, Ephemeroptera and in Odonata (dragonfly).

Activity 7.2

Respond to the following statements by writing YES or NO answers are in the appendices.
1. All winged arthropods are insects, but not all insects have wings
2. Flies and mosquitoes have two pairs of wings
3. Orthoptera and Ephemeroptera have wing venation close to fossil insects.
4. The primitive insect wing that is densely reticulated is known as the Archedictyon
5. The number and arrangement of the veins is of great taxonomic value
6. A broad evolutional trend among insects is complication of the wing by increase in venation
7. The spaces between wing veins are called cells
8. Insect wings are located in the abdomen
9. The Archedictyon wing has persisted in the present day
10. The Comstock-Needham system is a system of letters and numbers numbers for naming various parts of the insect wing.

7.4: Various types of insect wings

A broad evolutional trend among insects is simplification of the wing venation. This has occurred in 2 ways: first, by the strengthening of the anterior margin. Second, by reduction of veins in the rest of the wing. The wing of Ephemeroptera Orthoptera and Odonata are closest to the fossil insect wing. At the other end of the scale, are some Hymenoptera (suborder- Chalcidoidea ) whose wings have only the subcosta and part of the radius left.

In between, there are numerous modifications with regard to wing venation. The majority of insects have lost the anterior medial veins. In addition to variation in wing venation wings of insects vary in number, size, shape, texture, and the position at which they are held at rest. Some of these variations are discussed and illustrated below:

1. Wings with patterns, scale or hairs

Scaly wings front and hind wings covered with flattened setae (scales ). Some insects have membranes patterned by pigments contained in the epidermal cells. e.g Mecoptera and Typhlad. Some insects have wings clothed with scales, e.g. Lepidoptera (Butterflies and Moths). The wings of butterflies and moths are not membranous. Rather they are covered with small dust-like scales Pigments in the scales are responsible for the colours of many Lepidoptera. If the scales are removed, even bright butterflies lose their colors.
The wings of caddis flies are clothed with hair-like structures. Hairs and scales occur on wing membranes. Microtrichia are no-inverted spines on the wing membrane. Machrotrichia are inverted sensory hairs confined to wing veins; except in Trichoptera they occur also on wing membrane.

2. **Elytra** is the hard, sclerotized front wings that serve as protective covers for membranous hind wings. Fore wings of beetles (Coleoptera) and Dermaptera that are hardened and heavily sclerotized are called elytra. They protect the inner hind wings and the insect body. In some Coleoptera, elytra are fused along the dorsal line. In these flight is impossible. In Staphylinidae (Coleoptera), elytra are shortened covering only the anterior part of the abdomen.

3. **Tegmina**: The hardened (sclerotized fore wing of a grass hopper or locust is called Tegmen, plural tegmina. Such front wings are completely leathery or parchment-like in texture.

4. **Hemelytra**: A variation of the elytra is the hemelytra. The forewings of Hemiptera are said to be hemelytrous because they are hardened throughout the proximal two-thirds, while the distal portion is membranous. Unlike elytra, hemelytra function primarily as flight wings. These are the front wings that are leathery or parchment-like at the base and membranous near the tip found in Hemiptera and Heteroptera. In Heteroptera, only the basal part of the forewing is sclerotized. The distal parts remain membranous. Such a wing is called hemelytron.
5. **Halteres** are small, club-like hind wings that serve as gyroscopic stabilizers during flight. Diptera use only forewings in flight. The hind ones are reduced to tiny articulating knobs called halteres. They are used as balancers during flight.

![Halteres](image)

6. **Fringed wings**: Wings of Thysanoptera are peculiarly reduced. Each consists of a flattened rod with heavily fringed with long setae.

![Fringed wings](image)

7. **Brachypterous wings**
   In some insect order, one or both pairs of wings are short. They are called brachypterous wings. Such a wing is found in stick insects as shown below and also in the praying Mantis.

![Brachypterous wings](image)

8. **Hairy wings**: Tricoptera have front and hind wings clothed with setae (hairs).

![Hairy wings](image)

9. **Lace like wings**: The lace wings (Neuroptera) take their name from the many cross veins in the wings. The four wings are alike and membranous with many cross veins giving the appearance of lacy material as shown below:

![Lace like wings](image)
10. Wingless insects: Some insects - such as the ants and termites - are wingless. Wingless insects are found in nearly every order. Social insects e.g. ants (Hymenoptera) and termites (Isopota), frequently are wingless. Their adult sexual forms are winged. But after mating flight and migration to a new colony site, wings are dropped. But the lack of wings in termite worker soldier castes is embryological. True adult wingless insects are found in parasitic forms. E.g. bedbugs Cimex (Hemiptera), all members of Anoplura, Mallophaga and a Siphonaptera. Their wingless is secondarily acquired. They are descended from winged ancestors. Grylloblatiodea are the adult wingless non-parasitic group.

ACTIVITY 7.3

Name three different types of wing less insects

2. Describe the type of wing found in
   A Thrips (Thysanoptera)
   B Lace wings (Neuroptera)
   C Stick insects (Phasmida)
   D Moths and butterflies (Lepidoptera)

3. Define the following terms: A Hemelytron, B Elytron, C Halteres, D Tegmen

4. State a major difference between the insect wing and that of a bird.

7.4.1: special structures in insect wings

1. Hamuli: Hymenoptera have tiny hooks on their hind wings that hold front and hind wings together. These hooks are known as hamuli.

2. Frenulum: Lepidoptera have a bristle near base of hind wing that holds front and hind wings together. The bristle is known as a frenulum
**ACTIVITY 7.4**

1. Describe how insects use their wings to produce sound
2. Explain why the possession of wings is advantageous to insects
3. State the significance of learning the detailed insect wing structure

**7.5: Sound production by the insect wing**

In various groups of insects, the wings are modified for sound production and they may be retained for this function when they are no longer used in flight.

Striated ridge along the edge of are rubbed by a ridged area on the hind femur to produce sound in some coleopteran.

Some Lepidoptera produce sound by rubbing veins on the wings. In most Orthoptera e.g. crickets and sound is produced by rubbing the hind femora against the elytra. In crickets each species has a number of different songs used in different situations.

**Significance of sounds produced by insects**

The sounds produced by insects can be classified according to whether they represent signals to other species, that is, they are extraspecific, or whether they are signals to other members of the same species, that is, they are intraspecific.

Extra specific sounds are usually unorganized having no regular pulse repetition frequency and covering a broad spectrum of frequencies. Usually they are produced by both sexes and sometimes even the immature stages. Such sounds include stridulation and are concerned with defense or alarming others of a potential predator or alarming the predator. Sound mimicry is also common amongst insects of different species.

Intra specific sounds serve the following purposes:

- Calling, courtship, copulation, territoriality (aggression and alarm). Aggressive stridulation is well illustrated by crickets. Each male *Oecanthus* has a territory of some 50 sq. cm. In which he sings his normal song. If another male cricket intrudes the male sings an aggressive song quite distinct from other songs and the intruding males replies. Fighting may occur and the dominant male maintains the territory. Aggressive stridulation has the effect of spacing males over the largest possible area and at the same time reduces the interference during mating. Similarly the alternation of singing in some species may help an approaching female to locate the male. In bees sound together with visual cues indicate the distance of food source to other members of the same colony.

**Activity**

1. Name three different types of wing less insects
2. Describe the type of wing found in Thrips (Thysanoptera), Lace wings (Neuroptera), Stick insects and (Phasmida) Moths and butterflies (Lepidoptera)
3. Define the following terms: A Hemelytron, B Elytron, C Halteres, D Tegmen
4. State a major difference between the insect wing and that of a bird
5. Describe how insects use their wings to produce sound
6. Explain why the possession of wings is advantageous to insects

**LECTURE 8: THE INSECT ABDOMEN**

**Objectives**

The objectives of this lecture are to:

- Illustrate the insect abdomen to show the arrangement and number of the abdominal segments.
- Compare and contrast the abdomen of two different insects.
- Differentiate a female from a male insect using the external genitalia within the abdomen.
- Examine, draw and label all the basic structures found in the abdomen of a male and female insect.
- Identify abdominal appendages, where applicable and define their functions.
Describe the abdomen and abdominal appendages found in certain immature insects

8.1: Introduction

In lecture six and seven above, we studied the thorax and its appendages. Let us remind ourselves that the thorax is the second body part of an insect after the head. The third body part after the thorax is the abdomen. In this lecture we shall examine the abdomen of a grasshopper or locust by way of study notes as well as illustrations. You will be expected to construct as many as three illustrations of the abdomen of three different insects. You will need a hand lens and three different insects that are available in your surroundings.

8.2: The Abdomen

The abdomen is composed of nine to eleven segments, but the eleventh segment is complete only in Proturans and in embryos. The abdominal segments are more equally developed than are those of other regions of the body. The tergites and sternites are usually simple, undivided plates whilst the pleura are membranous. In some Diptera the tergites may be so strongly developed as to encircle the sternites completely so that they are hidden from view; this allows the abdomen to expand after a large meal, or when eggs are developing. The telson is vestigial, the only abdominal appendage in adult insects are a terminal pair of sensory cerci borne on the eleventh segment. As shown on the diagram below. The abdomen contains the organs of digestion, reproduction,

The cerci (singular circus) are slender appendages found posteriorly. They resemble little horns and are found on both males and females. The male genitalia are terminal but are largely enclosed. The female has a conspicuous ovipositor. The ovipositor consists of a pair of dorsal and ventral valves. These valves are moveable and are used by the female for digging a hole in the ground in which eggs are deposited.

Having learnt all these, can you identify the sex of your specimen?

The anus and reproductive organs are at the apex of the abdomen. The male usually possesses a median intermittent organ and a pair of claspers, which help to grip the female during copulation. The complexity of the external male genitalia varies widely and their structure is often of great taxonomic importance. In the female the external genitalia consist typically of three pairs of processes, which form together an egg laying organ called the ovipositor. In bees and wasps this is modified to form a sting organ. On the abdomen there usually ten pairs of spiracles which open into the tracheal system. The first segment of the abdomen in insects such as the grasshopper bears on each side an oval tympanic membrane that covers the auditory sac of hearing.

ACTIVITY 8.1

Using either a grasshopper or locust, examine the abdomen.
How many tergites do you find?
How many sternites do you find?
Towards the base of the first tergite on each side you will find the tympanum, a large ear drum or auditory membrane.
Can you find the spiracles?

The cerci (singular circus) are slender appendages found posteriorly. They resemble little horns and are found on both males and females. The male genitalia are terminal but are largely enclosed. The female has a conspicuous ovipositor. The ovipositor consists of a pair of dorsal and ventral valves. These valves are moveable and are used by the female for digging a hole in the ground in which eggs are deposited.

Having learnt all these, can you identify the sex of your specimen?

8.3: Abdominal appendages

Insects are believed to have originated from some myriapod-like ancestor with a pair of typical walking legs on each abdominal segment.
Typical legs found on the thorax never occurred in the ancestral insect. Some abdominal appendages occurring in present time insects are secondary structures, which have developed quite independently of the primitive appendages.

Primitive appendages on segment 8 and 9 have been modified as external genitalia - in some female insects there is an egg-laying structure in the posterior abdominal appendages. This enables the female to insert her eggs into special situations, within plant or animal tissue. This structure is the ovipositor. Appendages are absent from pregenital segments of the abdomen of adult winged insects except in the wingless groups. There are pairs of appendages on each of the first three segments of Protura. These function as locomotory organs.

8.3.1: Primitive abdominal appendages

1. Cerci
Appendages of segment 11 form a pair of structures called Cerci, which arise from the membranes between the paraproct and epiproct. In cases where segment 11 is absent cerci arises from segment 10. Cerci is present in wingless insects and hemimetabolous orders other than Hemiptera. Among the holometabolous insects only order Mecoptera have cerci.

Cerci variations
Cerci may be simple unsegmented structures as in Orthoptera or annulated as in Dictyoptera. Some are forceps and pincer like. Cerci may be very short and barely visible or extremely long or even longer than the insect body as in Thysanura, Ephemeroptera and Plecoptera. Even within a family the range and form of cerci vary considerably. Some cerci are featherlike as in Ephemeropteran Prosopistoma.

Sometimes cerci are different in two sexes of a species suggesting that they play a role in copulation e.g. cerci of female Calliptamas (Orthoptera) are simple cones but in the male they are elongate flattened structures with two or more lopes at the apex and armed with strong pointed structures. Similar dimorphism is found in the Embioptera where the left male circus is asymmetrical forming a clasping organ.

Functions of Cerci:
1. Movement - Cerci of Prosopistoma sp beat against water to produce a forwards driving force.
2. Respiratory - In larval insect groups e.g. Zygoptera cerci are modified to form gills. These are known as tracheal gills or caudal lamellae. Larval Zygoptera also have tracheal gills.
3. Food gathering - Forceps - pincers like cerci of Japygidae are used in catching prey.
4. Copulation - In Orthoptera and Embioptera cerci are used by males as claspers to hold onto the females.
5. Sense organs - Cerci are usually armed with trichoid sensilla. These sensilla are sensitive to tactile stimuli and to air movement and sometimes may act as sound receivers.

2. Furca and Retinaculum

Arising from the posterior end of the third and the fourth abdominal segment of many Collembola is a structure called furca and retinaculum - these is used for locomotion.

3. Adhesive tubes
From the first segment a median lobe projects between the last pair of legs. This lobe is the ventral tube - these tubes have two functions - as adhesive organs enabling the insect to walk over smooth or steep surfaces. The second function of the tubes is the absorption of water from substratum.

4. Styli
Segments 1-9 of members of Thysanura are some pairs of small unjointed sytli each inserted on a basal sclerite associated with the Styli are a median eversible vesicles in Diplura. The styli function as locomotory organs while the vesicles as in collembola can absorb water from the substratum.

5. Cornicles
Aphids have a pair of tubes known as **cornicles**, projecting from the dorsum segment 6. They function to permit the escape of a waxy fluid, which protects the aphid from predators.

**ACTIVITY 8.2**

**ACTIVITY 8.2; self evaluation**

Using a hand lens, examine the lateral sides of your insect.

Describe the structures that you see.

Can you locate slit-like openings on either side of the abdomen? These are the spiracles! Do you know their function?

If you do not their function there is no cause for alarm. You will learn more about them in a subsequent lecture.

**8.3.2: Abdominal appendages in immature insects**

A variety of abdominal appendages serving different functions are present in many insect larvae. Abdominal appendages present in the larval forms of holometabolous insects and other diverse aquatic larval forms are outlined below:

1. **Tracheal gills**
   Gills are present on the abdomen of larvae of the following insect groups: Ephemeroptera, Plecoptera, Megaloptera, Tricoptera, Coleoptera, and Zygoptera.

2. **Prolegs**
   Holometabolous larva - possess leg-like outgrowths of the body wall. These are called prolegs. Normally they are armed with spines or crochets, which grip the substratum. Prolegs also serve to hold onto prey in some diptera e.g. larva of *Vermileo* lives in a pit of dry soil. It lies ventral side up and prey which fall into the pit are quickly grasped against the thorax using the prolegs. Diversity of prolegs indicates that they have evolved along separate lines to serve various functions. Well developed prolegs are also found in lepidopteran larval which usually have a pair on each abdominal segments 3-6, & 10 climbing forms have prolegs pointed out, and suitable for grasping onto twigs. Even within the order Lepidoptera, the larval prolegs vary in position and number prolegs are also absent in some free living forms and in some leaf mining larval prolegs are also absent. Some prolegs in other insect groups totally lack crochets. When prolegs are not well developed their position is occupied by a raised pad armed with spines called creeping wells. In some insect grubs prolegs are modified for defensive purposes. In *Cerura* sp. the prolegs are slender projections. If larvae is touched the tip of the abdomen projects forward a slender pink process is everted from the end of each projection. Prolegs are common in larval diptera. Some Diptera larvae even possess several prolegs on each abdominal segment. Larval Tricoptera - possess anal prolegs on segment 10. They terminate in a claw, which enables the larvae to hold on to its larval case.

3. **Suckers**
   Larvae of some insect groups possess suckers which enable them to maintain their position along the sides of waterfalls, fast flowing streams and other turbid environments. Some larval Coleoptera have a pair of process called Urogomphi, which are outgrowths of the tergum of segment 9.

4. **Anal papillae**
   In larval mosquitoes and chironomids a group of papillae surrounds the anus. These papillae are concerned with salt regulation. In larval Sphingidae, a terminal spine arises from dorsum of abdominal segment 10.
ACTIVITY 8.3
Respond to the following statements by writing YES or NO. Answers are in the appendices.
1. Tergites are the plates found on the ventral (underside) of the insect abdomen.
2. The abdomen enclose the organs of digestion, reproduction, circulation and excretion.
3. The only abdominal appendage in adult insects are a terminal pair of cerci.
4. There are no spiracles in the abdomen of a terrestrial adult insect.
5. Abdominal appendages are present in aquatic larval forms as gills.
6. In some insect groups prolegs are modified into defense apparatus.
7. The abdomen is the second part of the insect body after the head.
8. Sternites are plates found laterally on the insect abdomen.

summary
- The ancestral insect had abdominal appendages, which were lost in the course of evolution.
- Abdominal appendages occurring in present time insects are secondary structures, which have developed quite independently of the primitive appendages.
- Tergites are the plates found on the ventral (underside) of the insect abdomen.
- Sternites and pleurites are plates found ventrally and laterally on the insect abdomen respectively.
- The abdomen enclose the organs of digestion, reproduction, circulation and excretion.
- The abdominal appendage in adult insects are a terminal pair of sensory cerci.
- Cerci is a primitive appendage arising from the 10th or 11th abdominal segment of wingless insects and hemimetabolous insects other than Hemiptera.
- Arising from the posterior end of the third and the fourth abdominal segment of many Colembola are a structure called furca and retinaculum – these are used for locomotion.
- The anus and reproductive organs are at the apex of the insect abdomen.
- Abdominal appendages are present in aquatic larval forms of Tricoptera, Plecoptera and Ephemeroptera as gills.
- Prolegs are abdominal appendages found in immature stages of some terrestrial insects. Some larval Coleoptera have a pair of process called Urogomphi, which are outgrowths of the tergum of segment 9. Aphids have a pair of tubes known as cornicles, projecting from the dorsum segment 6.
- In female insects, the external genitalia consists of three pairs of processes which form together an egg-laying organ called the ovipositor.
- In bees and wasps the ovipositor is modified to form a sting organ.

ACTIVITY 8.4
1. Describe the following, naming the particular insects that have them; Urogomphi, Cornicles, Crochets, and Prolegs.
2. Write short notes on Furca and Retinaculum.
3. List four functions of the insect cerci.
4. State the taxonomic significance of the external genitalia in insects.
LECTURE 9: FEEDING MODES AND THE DIGESTIVE SYSTEM

Objectives

At the end of this lecture you should be able to:

- Cite with specific examples, the various ways in which insects feed.
- Draw and label the various parts of the generalized insect digestive system, starting from the mouth to the anus.
- Describe the functions of the insect buccal cavity. Oesophagus, pharynx, crop, proventiculus, ventriculus, ileum, rectum and anus.
- State that insects have various modes of feeding, a phenomenon, which has greatly contributed to their success as it has enabled them to exploit varied food sources.
- Mention that here are four broad categories of feeding habits, namely predation, parasitism, saprophytic feeding and phytophagous feeding.
- State that some insects such as termites cultivate fungus.
- Describe mutual exchange of food among insects, a process known as trophallaxis.
- Show that the gut is modified in different insect groups to suit the varied diets.

9.1: Introduction

In all the previous lectures we have been examining the insect external structures starting from the head to the abdomen. We have completed studying the external morphology. We shall now start studying the internal systems.

We shall start with feeding systems and the digestive system.

Remember that in lecture eight we learned that the insect abdomen encloses certain organs such as the digestive system and other systems. In order to accomplish certain tasks in this lecture you will need ordinary pins, a rectangular tray, large enough to hold a freshly killed grasshopper or cockroach, a sharp pair of scissors, forceps, clean water and a hand lens.

Before we study the digestive system we shall first study the various ways in which insects feed.

9.2: Insect feeding modes

Insects feed on a very wide variety of animal, vegetable and dead organic materials. The fact that insects have adapted to a wide variety of foods has contributed to their success in that it enables them to exploit a wide range of habitats.

Insects have adapted to all types of diets. The mouthparts are therefore highly modified to suit different types of feeding habits and this was already discussed in lecture number five. The finding and recognition of such food involves various mechanisms depending on the insects. In most insects, vision and olfaction plays an important role in food finding. Feeding and ingestion involves modifications of mouthparts and physiological adaptations in various groups. Fluid feeders for instance often inject enzymes into the food and in blood-sucking insects, an anticoagulant may be injected. Predacious insects restrain their prey by force or by means of venom injected with the saliva or via a sting. A few insects grow fungus food and social insects go a step further and even store food and feed one another! There are four broad categories of the feeding modes (habits) of insects as described below:

9.2.1: Plant feeders
Nearly half of the species of insects feed on plants. Plant feeders may further be divided into two categories:

(a) **Phytophagous** - Those feeding on green plants.

(b) **Mycetophagous** - Those feeding on fungi.

Phytophagous insects are predominantly: Orthoptera, Lepidoptera, Homoptera, Thysanoptera (families cebalbycidae, Curculioidae and chrysomelidae) Hymenoptera (symphyta) and some Diptera. Most of these feed on higher plants but the aquatic larvae of some Plecoptera, Tricoptera and Ephemeroptera feed on algae. Fungus feeding larvae are common amongst Diptera. Dung/feeder include various Coleoptera, termites, the termites cultivate their fungi. You will learn more about this in lecture eighteen.

**ACTIVITY 9.1**

1. List the four broad categories of feeding modes in insects.
2. Mention a group of insects that cultivate their food.
3. State the sex(s) that suck vertebrate blood in these flies:
   (a) Tse-tse flies
   (b) mosquitoes
4. Define the following terms with specific insect examples:
   (a) Phytophagous
   (b) Mycetophagous
   (c) Saprophagous
   (d) Predation
   (e) Parasitism

**9.2.2: Predators**

Some predators occur in a number of the insect orders. Some insects are partially predaceous while others are predominantly predaceous. Predominantly predaceous groups are Odonata, Dictyoptera (manntodea), Heteroptera (reduviidae e.g. assassin bugs), larval Neuroptera, Mecoptera, Diptera and Hymenoptera. These predaceous groups feed mainly on other insects, but larval Lambyridae for instance, prey on snails.

**9.2.3: Saprophagous insects**

In these insects, larval food is quite different from the food of the adult insect. Decaying organic matter is a common source of food. Predominantly Saprophagous insects are larvae of Diptera and Coleoptera. In this habit of feeding, fungi may also form an important part of the diet.

**9.2.4: Parasitic insects**

Insect parasites may live on the outside (ectoparasites) or inside (endoparasites) of their hosts. Insect Ectoparasites comprises of the following:-

(a) All Siphonaptera

(b) All Mallophaga and Anoplura

(c) Some Heteroptera e.g Cimex sp. and some Reduviidae

(d) Various Diptera such as mosquitoes, black flies, biting midges and gnats, sand flies, horseflies and some Muscidae. Many of these suck vertebrate blood. In some cases such as mosquitoes and horse flies only females suck blood. In other cases as in tse-tse flies and stable flies, both sexes suck blood. Blood sucking insects are known as haematophagous insects.

Insect Endoparasites comprises of the following:-

Internal parasites, most of which are parasitic only as larva are found in the following insect groups

Diptera (warble flies, bot flies, blow flies, flesh flies) Internal parasites are also found in some Hymenoptera and Strepsiptera
9.2.5: Trophallaxis

Quite often in social insects, mutual exchange of food occurs, such behavior is known as trophallaxis.

Social feeding occurs in Hymenoptera e.g. bees, warps, ants and in a few non-social insects. During courtship, Empidae (Diptera) male present food to females.

9.3: The insect digestive system

The insect digestive system is also known as the alimentary canal or the gut. The alimentary canal comprises of three regions, foregut, midgut and hindgut as shown on Fig 9.1 below: Various parts of the gut may become modified anatomically and physiologically to perform various functions depending on the diet of the insects.

The foregut is commonly concerned with the storage of food and fragmentation of food into smaller particles before it passes to the mid gut.

The mid gut, which is lined by a delicate membrane, is primarily concerned with the production of enzymes and absorption of the products of digestion.

In some fluid feeding insects such as Heteroptera and Homoptera the gut has been modified to provide for rapid eliminations of the excess water taken in.

The mid gut, also called the Ventriculus or stomach is usually tubular. Most insects possess out pocketings of the mid gut called gastric caeca.

The position of the gastric caeca varies with groups, but they are commonly located at the anterior end of the midgut.

The hindgut or proctodeum consists of an anterior intestine (ileum) and a posterior rectum. Both of which are lined by cuticle. The hindgut conducts undigested material to the exterior via the anus but it also maintains the water and salt balance.

Digestion of cellulose by termites and certain wood-eating insects is made possible by the action of enzymes produced by protozoans, which inhabit the hindgut. Acetic acid formed by the breakdown of wood is actively absorbed by the hindgut epithelium in such insects.

The length of the gut is roughly correlated with the diet; insects feeding largely on protein diet tend to have a shorter gut than those feeding largely on carbohydrates although this is not always the rule.

Fig. 9.1: The insect digestive system

ACTIVITY 9.2

1. Name two words that are used to refer to the digestive system.
2. Describe the three regions of the insect gut.
3. State the other names for ventriculus and proctodeum respectively.
4. Explain how cellulose is broken down in the gut of termites.
5. Indicate why the insect gut may not be exactly the same in structure among all insect groups.

9.3.1: The foregut

The foregut comprises of the following regions:
1. Pharynx

The pharynx is the 1st part of the foregut after the buccal cavity. The pharynx has a series of dilator muscles inserted into it. These muscles are best developed in sucking insects especially Lepidoptera and Hymenoptera where the pharynx functions as a pump.

2. Oesophagus. The oesophagus is an undifferentiated part of the foregut serving to pass food from the pharynx to the crop.

3. Crop

The crop is an enlargement of the foregut in which food is stored. When not filled with food in some groups e.g. cockroaches it is filled with air in some fluid feeders. It is a lateral diverticulum. In general, secretions and absorption do not occur in the crop, this being limited by the impermeable intima.

4. Proventriculus

The proventriculus is a part of the foregut and is quite variable in structure and function. In insects that eat solid food, the proventriculus is usually modified as a gizzard and bears teeth or hard protuberances (teeth) for macerating and shredding food.

In fluid feeders it could be absent or present in the form of a simple valve opening into the mid gut. It thus retains food in the crop while permitting the forward passage of enzymes in some insects.

In between the extremes are some butter flies and honey bees in which the proventriculus has been specialized to form a regulatory function. It permits fluids and not solid food to enter the mid gut. This function is particularly important in the separation of pollen from nectar in bees.

9.3.2: The midgut

The midgut consists of the

- ventriculus, where most digestion is carried out
- gastric caeca which, if present provide greater area for digestion and absorption.
- peritrophic membrane; a semi-permeable membrane or matrix composed of chitin, and proteins. The membrane surrounds the food bolus and protects insects’ gut from abrasion and invasion by micro organisms and parasites but facilitates the digestive process by being permeable to digestive enzymes.

9.3.3: The hindgut

The hindgut consists of the

- ileum or anterior hindgut
- rectum

Both these areas reabsorb water and salts.

Valves are present to prevent back-flow of material within the gut

- cardiac (stomodeal) valve between fore and mid gut
- pyloric valve between mid and hindgut

ACTIVITY 9.3

Using a locust, grasshopper or cock roach carry out a dissection as follows:-
1. Cut off the legs and wings.
2. Dissect from the dorsal side
3. Make a longitudinal cut along the mid-dorsal line from the head to the posterior end of the abdomen. The trachea system will be visible as shiny white tubes.
4. Dorsally near the posterior part of the abdomen you will find the reproductive organs, testis in males and ovaries in females. Remove these.
5. Using forceps or a blunt pin carefully expose the gut by pushing aside remove the reproductive structures fat tissues and parts of the trachea.
6. Once the internal organs are exposed place the specimen inside a waxed bottom tray containing water.
7. Trace the gut from the head region to the anus.
8. Identify all the parts mentioned under section 9.
9. Draw, label fully and compare your drawing with figure 9.1 above.

Take note: Once you are through with the digestive system remove the entire system from the body cavity. You will then see the double the ventral nerve cord.

### 9.4: Other structures associated with the insect gut

Ø The gut is innervated by motor nerves, which control the movements of the gut and the passage of food along it.

Ø Various glands, associated with the mouthparts function mainly in the production of saliva. Most insects possess a pair of salivary or labial glands. These lie below the mid gut and have a common diet opening into the buckle cavity. In addition to salivary glands, some insects possess mandible glands.

Ø The long, slender Maligning Tubules of the excretory system are attached to the junction of the midget and hind gut.

**Summary**

In this lecture we have learnt that:

- Insects have various modes of feeding, a phenomenon, which has greatly contributed to their success as it, has enabled them to exploit varied food sources.
- There are four broad categories of feeding habits, namely predation, parasitism, Saprophytic feeding and phytophagous feeding.
- Some insects such as termites cultivate fungus!
- Insects engage in mutual exchange of food, a process known as trophallaxis.
- The generalized insect gut has three major parts; the fore gut, mid gut and hind gut.
- The fore gut comprises of the mouth pharynx, oesophagus, crop and proventriculus.
- The mid gut comprises of a long tube called ventriculus and gastric caecum.
- The hind gut comprises of the ileum, rectum and anus.
- The various regions of the gut perform various functions. The gut is also modified in different insect groups to suit the varied diets.

**ACTIVITY 9.4**

1. List the parts of the fore gut and hindgut.
2. Differentiate insect ectoparasites from endoparasites with specific examples.
3. Name two glands associated with the insect gut.
4. State the significance of the great variation in insect diets.

**LECTURE 10: THE INSECT CIRCULATORY SYSTEM**

**Objectives**

At the end of this lecture you should be able to:

- Explain the major differences between an insect circulatory system and the vertebrate circulatory system.
- Name the three sinuses in the insect body cavity.
- List the various functions of the insect circulatory system.
- Outline the structural lay-out of the insect circulatory system.
- State the physiological functions of the insect circulatory system.
- Define haemolymph, segmental vessels, ventral and dorsal diaphragm.

10.1: Introduction

In the last lecture we examined the insect digestive system in detail. In this lecture you will study lecture notes of the circulatory system. Take note that the circulatory system is located dorsally on an insect. For this reason you were not able to see it in your first dissection which was done on the dorsal side. As you were cutting along the dorsal side you were cutting through the dorsal circulatory system. In this lecture the circulatory system will be described in detail.

The insect circulatory system is responsible for the following:-

1. Movements of nutrients, salts, hormones, and metabolic wastes throughout the insect body
2. Sealing off of wounds through a clotting reaction
3. Encapsulates and destroys internal parasites or other foreign bodies
4. Generates hydrostatic pressure and aids in thermoregulation.

Insects, unlike vertebrates, have an open circulatory system with blood (Haemolymph) occupying the general body cavity (haemocoel). To facilitate circulation, the haemocoel is divided into three sinuses namely pericardial, perineural and perivisceral. The major structural component of an insect's circulatory system is a dorsal vessel that runs along the dorsal line for almost the whole length of the insect body. Within the abdomen, the dorsal vessel is called the heart. The heart is separated into chambers by structures (valves) called ostia. This is to ensure one-way flow of haemolymph. The aorta is a simple tube without ostia, which continues forward in front of the head and runs into the head. Haemolymph is made up of hemocytes, Phagocytes, plasma, (amino acids, proteins, sugars, and inorganic ions). Closely associated with the heart are the aliform or alary muscles. These stretch from one side of the body to the other. Other structures that could be related to the insect circulatory system include Segmental vessels, Phagocytic organs, Ventral diaphragm, Dorsal diaphragm and Accessory pulsatile organs.

10.2: An "open" Insect circulatory system

The circulatory system of insects differs from that of vertebrates and many other invertebrates in being "open". In an open system, blood (usually called hemolymph) spends much of its time flowing freely within body cavities where it makes direct contact with all internal tissues and organs. Haemolymph is confined to vessels during only a portion of its circuit through the body. The remainder of its journey takes place within the body cavity called the haemocoel. The haemocoel is divided into chambers called sinuses; the pericardial, perivisceral and perineural sinuses.

The circulatory system is responsible for movement of nutrients, salts, hormones, and metabolic wastes throughout the insect's body. In addition, it plays several critical roles in defense: it seals off wounds through a clotting reaction, it encapsulates and destroys internal parasites or other invaders, and in some species, it produces distasteful compounds that provide a degree of protection against predators. The hydraulic (liquid) properties of blood are important as well. Hydrostatic pressure generated internally is used to facilitate hatching, molting, expansion of body and wings after molting, physical movements (especially in soft-bodied larvae), reproduction (e.g. insemination and oviposition), and evagination of certain types of exocrine glands. In some insects, the blood aids in thermoregulation: it can help cool the body by conducting excess heat away from active flight muscles or it can warm the body by collecting and circulating heat absorbed while basking in the sun.

10.3: Dorsal vessel

dorsal vessel is the major structural component of an insect's circulatory systems shown. This tube runs longitudinally through the thorax and abdomen, along the inside of the dorsal body wall. In most insects, it is a fragile, membranous structure that collects hemolymph in the abdomen and conducts it forward to the head. The dorsal vessel runs along the dorsal midline, just below the terga, for almost the whole length of the body.
Anteriorly it leaves the dorsal wall and is more closely associated with the alimentary canal, passing under the cerebral ganglion just above the oesophagus. The dorsal vessel is divided into two regions: a posterior heart in which the wall of the vessel is perforated by incurrent and sometimes also by excurrent ostia; and an anterior aorta which is a simple, unperforated tube. The wall of the dorsal vessel in the heart and the aorta is contractile and consists of a single layer of cells in which circular or spiral muscle fibrils are differentiated. These cells are bounded on both sides by a homogeneous membrane and on the outside there is usually some connective tissue. A network of tracheoles is often present, especially round the posterior part of the heart.

10.4: The heart

In the abdomen, the dorsal vessel is called the heart as illustrated on figure 10.1 below. It is divided segmentally into chambers that are separated by valves (ostia) to ensure one-way flow of hemolymph. In front of the heart, the dorsal vessel lacks valves or musculature. The heart may be directly bound to the dorsal body wall or suspended from it by elastic filaments.

Fig.10.1: The insect circulatory system and course of circulation

10.4.1: Incurrent ostia

The incurrent ostia are vertical, slit-like openings occurring in the heart wall. There may be nine pairs of incurrent ostia in the abdomen and up to three pairs in the thorax. The anterior and posterior lips of each ostium are reflexed into the heart so that they form a valve permitting the flow of blood into the heart at diastole, but preventing its outward passage at systole. During diastole the lips are forced apart by the inflowing blood. When diastole is complete the lips are forced together by the pressure of blood in the heart and they remain closed throughout systole. Towards the end of systole the valves tend to become evaginated by the pressure but they are prevented from turning completely inside out by unicellular thread to the inside of the heart. During systole this is pressed against the wall of the heart so that the escape of blood is prevented.

10.4.2: Excurrent ostia

These are usually paired entro-lateral openings in the wall of the heart without any internal valves. The number of excurrent ostia varies with insect groups. Externally each opening is surrounded by a papilla of spongiform multinucleate cells, which expands when the heart contracts, so that blood passes out, and contracts when the heart relaxes, so that the entry of blood is prevented.

10.4.3: Segmental vessels

These are usually paired entro-lateral openings in the wall of the heart without any internal valves. The number of excurrent ostia varies with insect groups. Externally each opening is surrounded by a papilla of spongiform multinucleate cells, which expands when the heart contracts, so that blood passes out, and contracts when the heart relaxes, so that the entry of blood is prevented.

10.4.4: Phagocytic organs
The phagocytic organs are found in the anterior part of the abdomen of Tettigoniodea and Crylloidea. They are flattened triangular sacs opening ventro-laterally from the heart by narrow connections, at which there are eccentric valves, and then fanning out between the aliform muscles. Two to four pairs may be present. The ventral wall of these organs is formed by the dorsal diaphragm, the dorsal wall by phagocytic cells, which are multinucleate and occupy part of the lumen of each sac. These organs appear to act as filters removing dyes and particles from the blood, which is forced into them.

10.5: The Aorta

The aorta is a simple tube without ostia, which continues forward in front of the heart to the head and empties near the brain. Hemolymph bathes the organs and muscles of the head as it emerges from the aorta, and then haphazardly percolates back over the alimentary canal and through the body until it reaches the abdomen and re-enters the heart.

10.6: The alary muscles

Closely associated with the heart are the aliform, or alary muscles. These stretch from one side of the body to the other just below the heart. Usually they fan out from a restricted origin on the tergum, the muscles of each side meeting in a broad zone at the midline. The aliform muscles form an integral part of the dorsal diaphragm, which spreads between them as a fenestrated connective tissue membrane. It is usually incomplete laterally so that the pericardial sinus is broadly continuous with the perivisceral sinus in this region. The lateral limits are often indefinite and are determined by the presence of muscles or tracheae or the origins of the aliform muscles.

A pair of alary muscles are attached laterally to the walls of each chamber. Peristaltic contractions of these muscles force the hemolymph forward from chamber to chamber. During each diastolic phase (relaxation), the ostia open to allow inflow of hemolymph from the body cavity. The heart's contraction rate varies considerably from species to species -- typically in the range of 30 to 200 beats per minute. The rate tends to fall as ambient temperature drops and rise as temperature (or the insect's level of activity) increases. Some of the connective tissue fibers form a plexus, which extends to the heart wall, but in some insects, such as dipterous larvae, the aliform muscles are inserted directly into the walls of the heart instead of meeting beneath it. Orthopteroids may have as many as ten abdominal and two thoracic pairs of aliform muscles, but other insects the number is reduced. Geoconsae sp., for instance have from four to seven pairs.

10.7: Dorsal and ventral diaphragm

The ventral diaphragm is a horizontal septum just above the nerve cord cutting off the perineural sinus from the main perivisceral sinus it is present in both larvae and adults of Odonata, Orthoptera, Hymenoptera and Neuroptera, but is only found in adults of Mecoptera and the lower Diptera. No ventral diaphragm is present in the other orders of insects except in Lepidoptera where it is unusual in having the nerve cord bound to its ventral surface by connective tissue.

In several orders the ventral diaphragm is restricted to the abdomen, but in Orthoptera it is also present in the thorax. Posteriorly it does not extend beyond the posterior end of the nerve cord.

The structure of the ventral diaphragm varies. For instance, in the thorax of grasshoppers it is a delicate membrane with little or no muscle, but in the abdomen it becomes a solid muscular sheet. Its structure may also vary with age and in Corydalis sp. it forms a solid sheet in the larva, but a fenestrated membrane in the adult.

The contractions of the ventral diaphragm are probably myogenic and are propagated by tension, while nervous inhibition reduces the frequency with which contractions occur.

10.8: Accessory pulsatile organs

In some insects, in addition to the dorsal vessel, pulsatile organs are located near the base of the wings or legs. They are concerned with maintaining circulation through the appendages. These muscular “pumps” do not usually contract on a regular basis, but they act in conjunction with certain body movements to force hemolymph out into the extremities. In the mesothorax and sometimes also in the metathorax there is a pulsatile organ concerned with the circulation through the wings.

10.9: Innervation of the heart

In some insects, such as Anopheles sp., the heart is entirely without any nerve supply although there are segmental nerves to the aliform muscles. On the other hand the heart of Periplaneta sp. is innervated from three sources. Nerves from the corpora cardiaca and from the segmental ganglia combine to form a longitudinal nerve on either side of the heart from which nerve endings ramify in the wall of the heart and the aliform muscles. In addition, supposedly sensory fibers arise from the heart and join the sensory nerves in the dorsal body wall. Between these two extremes are various intermediate degrees of innervation and Prodenia sp., for instance, has only segmental nerves.
In the cockroach, and probably in most orthopteroids, scattered nerve cells, known as ganglion cells, occur along the lateral heart nerves, but these are not always present in other insects.

10.10: Haemolymph

About 90% of insect hemolymph is plasma: a watery fluid usually clear, but sometimes greenish or yellowish in color. Compared to vertebrate blood, it contains relatively high concentrations of amino acids, proteins, sugars, and inorganic ions. Over wintering insects often sequester enough ribulose, trehalose, or glycerol in the plasma to prevent it from freezing during the coldest winters. The remaining 10% of hemolymph volume is made up of various cell types (collectively known as hemocytes); they are involved in the clotting reaction, phagocytosis, and/or encapsulation of foreign bodies. The density of insect hemocytes can fluctuate from less than 25,000 to more than 100,000 per cubic millimeter, but this is significantly fewer than the 5 million red blood cells, 300,000 platelets, and 7000 white blood cells found in the same volume of human blood. With the exception of a few aquatic midges, insect hemolymph does NOT contain hemoglobin (or red blood cells). Oxygen which have haemoglobin is delivered by the tracheal system, not the circulatory system.

10.11: Course of circulation

In normal circulation the blood is pumped forwards through the heart at systole, passing out of the heart via the excurrent ostia and, anteriorly, from the aorta. The valves on the incurrent ostia prevent the escape of blood through these openings. The blood driven forwards by the heart increases the blood pressure anteriorly in the perivisceral sinus so that blood tends to pass backwards along a pressure gradient. Blood percolates down to the perineural sinus where it is agitated by movements of the ventral diaphragm, which assist the blood supply to the nervous system and possibly produce a backward flow of blood. The dorsal diaphragm is usually convex above so that contraction of the alary muscles tends to flatten it. This flattening increases the volume of the pericardial sinus at the expense of the perivisceral sinus. Coordinated movements of the body muscles gradually bring the blood back to the dorsal sinus surrounding the hearts. Between contractions, tiny valves in the wall of the hearts open and allow blood to enter and pass up into the pericardial sinus and then at diastole is drawn into the heart through the incurrent ostia.

ACTIVITY 10.1

Write True or False against the following statement:-
1. Insects have a closed circulatory system.
2. The incurrent and excurrent ostia are found in the aorta of insects.
3. The major structural component of an insect’s circulatory system is a dorsal vessel.
4. Peristaltic contractions of alary muscles force the hemolymph forward from chamber to chamber in insects.
5. Insect blood is called haemolymph.
6. The key function of the insect circulatory system is to transport oxygen.
7. The dorsal vessel is referred to as the heart when it is within the insect’s abdomen.
8. The heart is innervated by nerves in all insects.
9. Glycerol in plasma helps to prevent it from freezing in over wintering insects.
10. The Dorsal vessel is located ventrally in insects.

Summary

In this lecture we have learnt that:

- The insect circulatory system is responsible for the following:
  1. Movements of nutrients, salts, hormones, and metabolic wastes throughout the insect body
  2. Sealing off of wounds through a clotting reaction
  3. Encapsulates and destroys internal parasites or other foreign bodies
  4. Generates hydrostatic pressure and aids in thermoregulation.
Insects, unlike vertebrates, have an open circulatory system with blood (Haemolymph) occupying the general body cavity (haemocoel).

To facilitate circulation the haemocoel is divided into three sinuses namely pericardial, perineural and perivisceral.

The major structural component of an insect’s circulatory system is a dorsal vessel that runs along the dorsal line for almost the whole length of the insect body.

Within the abdomen the dorsal vessel is called the heart. The heart is separated into chambers by structures (valves) called ostia. This is to ensure one-way flow of haemolymph.

The aorta is a simple tube without ostia, which continuous forward in front of the head and runs into the head.

Haemolymph is made up of hemocytes, Phagocytes, plasma, (amino acids, proteins, sugars, and inorganic ions).

Closely associated with the heart are the aliform or alary muscles. These stretch from one side of the body to the other just below the heart.

Other structures that could be related to the insect circulatory system include;

1. Segmental vessels
2. Phagocytic organs
3. Ventral diaphragm
4. Dorsal diaphragm
5. Accessory pulsatile organs

The heart is innervated by nerves in some insects such as the cockroach, but is entirely without innervation in others such as the mosquito.

LEcTURE 11: THE EXCRETORY SYSTEM

Objectives

At the end of this lecture you should be able to:-

- Describe the Malphigian Tubules
- Locate and draw the Malphigian Tubules from a general insect dissection.
- List excretory structures found in insects, other than the Malphigian Tubules.
- Discuss how terrestrial insects maintain a salt/water balance
- State other functions of Malphigian Tubules besides excretion
- nephrocytes, gut, labial glands and the male accessory glands
- Describe Urate cells, goblet cells, nephrocytes
- State functions of the Malphigian Tubules other than excretion

11.1: Introduction.
In the last lecture we learnt that the Malpighian Tubules are associated with the insect gut. In this lecture we shall learn that the Malphigian Tubules are the main excretory structures found in the body of an insect. The physiological functioning of the Malphigian Tubules will be demonstrated. Excretory products will be mentioned and excretory structures other than the Malphigian Tubules will be discussed.

Salt and water regulation in terrestrial, fresh water and salt water insects will be covered as part of the wider topic of excretion.

11.2: The Malphigian Tubules

The Malphigian Tubules (M.T.) are long thin, blindly ending tubules arising from the gut near the junction of midgut and hindgut and lying freely in the body cavity. The tubules may open independently into the gut or may join into groups to form a ureter, which then enters into the gut. The wall of the M.T is usually one cell thick on a tough basement membrane. M.T of some insects have muscle strands surrounding them but this is not the rule. These muscles produce writhing movements of the tubules in haemolymph ensuring maximum contact with the haemolymph. M.T are absent in aphids and Collembola. In Diplura, Protura and Strepsiptera they occur in the form of a papillae. In many Coleoptera and larval Lepidoptera the distal parts of the M.T. are closely associated with the rectum, forming a convoluted layer over its surface. This kind of network or arrangement is called the Cryptonephridial arrangement (C.A). The C.A is concerned with improving the uptake of water from the rectum and is absent from the majority of aquatic insects. Below is a diagram showing the physiological functioning of the Malphigian Tubules.

![Diagram of Malphigian Tubules](image)

11.3: Insect Excretory products

What are the excretory products in insects? They are:

Ø Ammonia- ammonia is highly toxic so it can be excreted in insects with ample supply of water such as those in fresh water or extremely moist environments.

Ø Uric acid- excreted in terrestrial insects

Ø Urea- excreted in small amounts

Ø Allantoin- excreted in some insects e.g. Dysdercus spp.

Ø Arginine/Histidine/other nitrogenous wastes- these are excreted unchanged by blood feeders such as the Tse-tse flies.

11.4: Nephrocytes

Nephrocytes or pericardial cells are special types of excretory cells with a single nucleus that occur singly or in groups in various parts of the insect body. They are usually present on the surface of the heart. The nephrocytes undergo cycles of development and they bud off pinosomes. Within the nephrocytes pinosomes are believed to coalesce and their contents are degraded and products held in a large vacuole, which is ultimately discharged into haemolymph. It is believed in this way materials too complex for immediate excretion are removed from haemolymph. Nephrocytes also take up dyes and probably colloidal particles from haemolymph.

11.5: Excretion other structures
EXCRETION BY THE GUT
In some insects such as cockroaches the M.T contain uric acid, but uric acid granules are also present in the wall of hindgut. This suggests that the hindgut may have an excretory function. Uric acid also occurs in the midgut of various caterpillars, larval Hymenoptera, some larval Diptera. Some insects (blow fly larvae) excrete ammonia directly to the gut without involving the M.T. In aquatic insects the ammonia may be secreted into the rectum.

LABIAL GLANDS
In Collombola where M.T are absent labial glands take up dyes from haemolymph and are also believed to be excretory in function.

MALE ACCESSORY GLANDS
In the cockroach Blatella uric acid accumulates in a part of the male accessory glands. Here it is temporarily stored and then is poured out over the spermatophore during copulation.

STORAGE EXCRETION
Waste materials may be retained in the insect body in a harmless form instead of being passed out with urine. This is known as storage excretion. There are specialized cells in the insect fat body called Urate cells that serve this function. In such insects, uric acid accumulates in the urate cells and is subsequently discharged through the M.T. In caterpillars special cells known as goblet cells in the midgut accumulate heavy metals such as sulphides which are eventually discharged from the body. Uric acid may also accumulate in the epidermis of some insects e.g. Rhodnius during molting and is subsequently removed after each molt is completed. Similarly in Pieris (Lepidoptera) uric acid produced during pupal instars is stored mainly in the scales of the wing.

11.6: Salt and water regulation in terrestrial insects
The water content of insects vary from 50 to 90 % of the body weight. Reduction of water content ultimately leads to death. Inorganic salts are also important in tissues. Together salts, and water produce osmotic effects which will affect the distribution of water. Hence it is essential that the salt and water content of tissues is regulated so as to maintain an optimal balance. The problems of insects in regulating salts and water vary according to their habitats and so terrestrial insects, fresh water and salt water have to be considered separately.

The balance of salts in terrestrial insects is done by the M.T and subsequent selective reabsorption in the rectum.

Terrestrial insects lose water in the following ways: Evaporation, Respiratory/excretory surfaces, Faeces and urine. If terrestrial insects must survive, water loss must be kept to a minimum and must be offset by water gain from other sources. Water loss through the cuticle is restricted by the presence of a waxy layer in the exoskeleton. Insects living in dry environments, such as the flour beetles conserve most of their water and excrete very dry Faeces and solid uric acid.

To offset the inevitable water loss by evaporation and excretion, water must be gained from other sources as outlined below :-

Ø Water gain from moist food; most insects gain water from their food and may select foods with high water content. Other insects have efficient regulatory mechanisms and therefore require very little water. If food content is low in water the insect may eat more than it ordinarily requires in order to extract extra water from it.

Ø Absorption of water through cuticle; some insects are able to absorb any little water that drops onto the cuticle especially in the immature stages. Some insects have also developed special structures, which are capable of absorbing water from water vapor.

Ø Water gain through drinking; many adult insects and larvae of holometabolous insects actively drink water. They have specific receptors and sensilla and stimulation of these leads to drinking.

Ø Water as an end product; when water is known as metabolic water and is an end product of oxidative metabolism, such water is made use of by dehydrated insects.

Ø Fluid feeding; Insects, which feed on fluids, are unusual amongst terrestrial insects in that at least for a time after feeding, their bodies contain excess water. In such insects the excess is reduced by rapid elimination of water from the body (rapid diuresis). Other insects such as Homoptera have anatomical adaptations for rapid elimination of water. Diptera and Lepidoptera store excess fluid in an impermeable crop so that the haemolymph does not become over diluted.

ACTIVITY 11.1
Write True or False against the following statements:-
1. Ammonia is excreted by insects in extremely dry environments.
2. Malpighian Tubules are absent in Collembola.
3. Histidine, arginine and other nitrogenous waste are excreted by some blood-sucking insects such as tsetse flies.
4. The cryptonephridial arrangement is present in the majority of aquatic insects.
5. Uric acid is excreted in terrestrial insects.
6. The Malpighian Tubule may occur in the form of a simple papillae as in Diplura and Protura.
7. Another name for Nephrocytes is pericardial cells.
8. Urate and goblet cells are associated with storage excretion.
9. The Malpighian tubules are long tubules found in the insect head.
10. Urea is excreted by insects in small amounts.

11.7: Salt water regulation in fresh water insects

To avoid passage of water into the insect the cuticle of some of these have a reversed monolayer on the outside of the waxy cuticular layer.

If insects in fresh water take up excess water through the papillae the excess is offset by production of copious urine.

In the event that fresh water insects lose salts to the environment, the salts are actively reabsorbed by the rectum. Sodium, Potassium and Chloride are known to be actively reabsorbed by the rectum, anal papillae and rectal gills.

11.8: Salt water regulation in salt-water insects.

Insects living in salt water environments have the problem of osmotic water loss and excess salt gain. The lost water is replaced by controlled drinking and absorption in the midgut. The midgut of such insects is able to withstand high salt concentration. Excess salts taken in with food is eliminated in the urine after controlled reabsorption from the rectum.

11.9: Other functions of the Malphigian Tubules

In a few insects the M.T are modified for functions other than excretion. In larval Neuroptera the M.T. are silk producing and the silk is used to form the pupal cocoon. In some insects the M.T. can produce sticky substances for covering eggs after they have been laid.

In larvae of a fly (Bolitophila lumunosa) the enlarged distal ends of the M.T. form a luminous (light producing) organ.

summary

- Malpighian Tubules are the main excretory structures found in the body of an insect.
- The excretory products in insects are: Ammonia; Uric acid; excreted in terrestrial insects; Urea; excreted in small amounts; Allantoin; excreted in some insects e.g. Dysdercus spp. Arginine; Histidine; and other nitrogenous wastes.
- The balance of salts in terrestrial insects is done by the M.T and subsequent selective reabsorption in the rectum.
- Other organs or structures in an insect that play an excretory role are nephrocytes, gut, labial glands and the male accessory glands.
- Other functions of the Malphigian tubules include silk production; light production and production of a sticky substances for covering eggs after they have been laid.
- When waste materials are retained in the insect body in a harmless form instead of being passed out with urine the process is termed storage excretion.
- Urate and goblet cells play a role in storage excretion.

ACTIVITY 11.2

1. How do insects that live in dry environments conserve water?
2. Discuss the Cryptonephridial arrangement.
3. List three other functions of the Malpighian Tubules besides excretion.
4. Write short notes on the following: - goblet cells, urate cells, nephrocytes, diuresis, and pinosomes.

LECTURE 12: THE INSECT RESPIRATORY SYSTEM

Objectives
The objective of this lecture is to understand how insects obtain oxygen

12.1: Introduction

Insect are tracheate meaning they obtain air through a system of tubes called trachea.

12.2: The tracheal system

Diffusion alone can account for the gaseous requirements of the tissues of most insects at rest, but in larger insects and during activity, demands for oxygen is greater. To meet this demand the insects have a tracheal system (Figs. 12.1) through which air is pumped in and out of the body.

The tracheal system comprises of:

1. Trachea are the internal tubes which branch into finer tubes and extend to all parts of the insect body and become intracellular in the muscle fibres. Oxygen is therefore carried directly to its sites of utilization and blood is not concerned with gas transport. The trachea open to the outside through pores called spiracles. The spiracles are situated laterally in the body. Generally, there is one pair of spiracle per segment.

2. Spiracles. The spiracles are situated laterally in the body. Generally, there is one pair of spiracle per segment. The spiracles have some closing mechanism, which limits water loss from the respiratory surfaces. The spiracles open in response to a low concentration of oxygen or a high concentration of carbon dioxide in tissues. The trachea are lined with a cuticle called intima. A spiral thickening of the intima is called teanidium. The teanidum prevent the collapse of the trachea if pressure within is reduced. Trachea pump air in and out of the tracheal system by expanding and collapsing air sacs. Air sacs are enlarged parts of the trachea whose volume can be changed by movements of the insect body.

3. Tracheoles. Tracheoles give rise to finer tubes called tracheoles. Tracheoles are intracellular and are closely associated with tissues and muscle fibres where they end blindly as shown above to the right.
ACTIVITY 12.3

Fill in the blanks in the following sentences:

1. Trachea open to the outside of an insect through ......................

2. The cuticle lining the trachea is called ..................................

3. Large parts of the trachea, whose volume can be changed by movements of the insect body are called ............................

4. .................. prevent the collapse of three trachea if pressure within is reduced.

5. ................. branch and give rise to finer tubes called tracheoles.

6. The spiral thickening of the intima is called ............................

7. .................. are intracellular and are closely associated with tissues and muscles.

8. Apart from the tracheal system small-bodied insects can get sufficient oxygen through the process known as ..................through the cuticle.

9. Trachea pump air in and out of the tracheal system by expanding and collapsing of ......................

12.3: Arrangement and distribution of the trachea

Trachea arise from spiracles. Trachea from neighboring spiracles anastomose to form lateral longitudinal trunks running the length of the body. These lateral longitudinal trunks are on either side of the body and are the largest trachea. There are also Dorsal and Ventral longitudinal trunks depending on the insect group.

The longitudinal trachea are connected to those of the other side of the body by transverse commissural trachea. Smaller branches of trachea give rise to tracheoles, which run into body tissues and cells (see fig 12.1). From the spiracles oxygen that has passed through the tracheal system ultimately reach the mitochondria in order to play a role in oxidation processes. Carbon dioxide follows the reverse path back into the spiracles.

To some extent the distribution and abundance of the trachea and spiracles reflect the demand for oxygen by different tissues. With the exception of the order Diplura, the largest number of spiracles found in insects is ten (10) pairs, two in the thorax and eight in the abdomen. The insect respiratory system may be classified on the basis of the number and distribution of the functional spiracles as follows:

A. POLYPNEUSTIC - At least 8 functional spiracles on each side of the body.
B. OLIGOPNEUSTIC - One or two functional spiracles on each side of the body.
C. APNEUSTIC - No functional spiracle. Apneustic does not mean that insects have no tracheal system, the insect has a tracheal system but the trachea do not open to the outside.

The arrangement and distribution of the tracheal system varies with different insect groups.

Fig.12.1: Dorsal & Ventral tracheal trunks
12.4: Insects obtaining oxygen from air

a. Periodic visits to the surface

The majority of aquatic insects obtain oxygen from air during periodic visits to the surface of water.

b. Respiratory siphons

A few insects maintain a semi-permanent connection with air via a long respiratory siphon. In many aquatic insects with siphons, only the posterior spiracles are functional and these are normally carried on the siphons. Such a structure is referred to as a telescopic respiratory siphon.

Problems facing all insects, which come to the surface, are those of breaking the surface film and prevention of water entry into spiracle. The problem is solved in two ways;

1. The nature of the cuticle waxy layer provides some resistance to wetness.

2. The whole surface of the cuticle may possess hydrofuge hairs or valves so that it is not readily wetted. Insects also produce oily secretions in the immediate neighborhood of the spiracles, which also gives resistance to wetting.

C. Air stores

Some insects have extra-tracheal air store. Such insects carry a bubble of air down into water as they dive. The spiracles open into this bubble so that it provides a store of air, additional to that contained in the tracheal system.
. Name the largest tracheal trunk.

2. State the tracheal trunk that connects longitudinal trachea of the other side of the body.

3. Indicate the tracheal trunk that supplies oxygen to the insect;
   (a) heart and dorsal muscles
   (b) gonads, legs and wings
   © central nervous system
   (d) Antennae
   (e) Mouthparts

4. Draw the tracheal system, showing the structural arrangement of the spiracles, trachea, tracheoles, body tissues and organs.

12.5: Insect obtaining oxygen from water

The spiracles of aquatic insects will open into a film of air so that oxygen readily passes from water into the tracheal system.

**Diffusion through the cuticle**

In all insects living in water particularly larval forms some inward diffusion of oxygen takes place through the cuticle in these forms the cuticle is very permeable. In these forms the tracheal system is fluid filled and oxygen obtained in this way oxygen passes through the cuticle into haemolymph and is sufficient to support the normally small size larvae such as black fly (Simulium) larvae and Chironomus larvae.

**Tracheal gills.**

Tracheal gills or caudal lamellae are a network of leaf like extensions of the body to form gills. The cuticle is very thin in these extensions. the extensions contain a network of tracheoles and the tracheal system is closed and spiracles are not functional. Oxygen diffuses through the cuticle into the tracheal system. Tracheal gill are found in larval Plecoptrea and larval Tricoptera

12.6: Aquatic insects obtaining oxygen from plants

A number of insects obtain oxygen by thrusting their spiracles into the aerenchyma of aquatic plants. This habit occurs in the larvae and pupae of a mosquito (Mansonia spp.). It also occurs in larval stages of some beetle, larval and pupal stages of some Diptera., which inhabit mud containing very little oxygen.

**ACTIVITY 12.5**

1. Define caudal lamellae and aerenchyma and state their role in insect respiration.

2. Cite circumstances under which diffusion alone, through the cuticle could
sustain an insect.

3. State why water is prevented from entering spiracles of aquatic insects.

12.7: Respiration in parasitic insects

Endoparasitic insects employ various methods of obtaining oxygen, generally comparable with those used by aquatic insects. The majority of endoparasites obtain some oxygen by diffusion through the cuticle from host tissues. Endoparasites with greater oxygen requirements communicate with the outside air either through the body wall of the host or via a respiratory system. They use a posterior spiracle to obtain oxygen. The spiracles of such larva open into the funnel-shaped inner end of a pedicel and make contact with the outside air. Other parasitic larva use the posterior spiracle to pierce the body wall of the host.

12.8: Haemoglobin respiration

In some very rare cases insects have respiratory pigments such as haemoglobin to provide a short-term store for oxygen. The best-known examples are the aquatic larva of *Chironomus* and related insects, the aquatic *Anisops* sp. and endoparasitic larvae of *Gasterophilus* sp.

**ACTIVITY 12.6**

1. Define the terms Ploypneustic, oligopneustic and aphneustic.

2. Outline the two ways by which aquatic insects obtain oxygen.

3. Compare and contrast salt and water regulation in terrestrial and aquatic insects.

4. Write short notes on haemoglobin respiration and respiration by parasitic insects.

**summary**

In this lecture we have learnt that:-

- In larger insects and during activity, demands for oxygen is greater. To meet this demand the insects have a **tracheal system** through which air is pumped in and out of the body.
• The tracheal system consists of tubes that open to the outside through spiracles. The tracheal system is significant in terrestrial insects. Aquatic and parasitic insects have devised other modes of respiration.
• Trachea branch into finer tubes called tracheoles and these extend to all parts of the insect body and become intracellular in the muscle fibres and organs. Oxygen is therefore carried directly to its sites of utilization and Haemolymph (blood) is not concerned with gas transport.
• The insect respiratory system may be classified on the basis of the number and distribution of the functional spiracles as follows:
  - POLYPNEUSTIC – At least 8 functional spiracles on each side of the body.
  - Oligopneustic - One or two functional spiracles on each side of the body.
  - Apneustic - No functional spiracle. Apneustic does not mean that insects have no tracheal system, the insect has a tracheal system but the trachea do not open to the outside.
• The tracheal system is significant in terrestrial insects. Aquatic and parasitic insects have devised other modes of respiration.
• Aquatic insects obtain oxygen from air through telescopic respiratory siphon, air stores, and by periodic visits to the surface.
• Aquatic insects obtain oxygen from water by diffusion through the cuticle, and by means of tracheal gills.
• A number of insects obtain oxygen by thrusting their spiracles into the aerenchyma of aquatic plants. This habit occurs in the larvae and pupae of a mosquito (Mansonia spp.), it also occurs in larval stages of some beetle, larval and pupal stages of some Diptera.
• The majority of endoparasites obtain some oxygen by diffusion through the cuticle from host tissues. Endoparasites with greater oxygen requirements communicate with the outside air either through the body wall of the host or via a respiratory system. They use a posterior spiracle to obtain oxygen. The spiracles of such larva open into the funnel-shaped inner end of a pedicel and make contact with the outside air. Other parasitic larva use the posterior spiracle to pierce the body wall of the host.
• In some very rare cases insects have respiratory pigments such as haemoglobin to provide a short term store for oxygen. The best-known examples are the aquatic larva of Chironomus and related insects, the aquatic Anisops sp. and endoparasitic larvae of Gasterophilus sp.

LECTURE 13: THE INSECT NERVOUS SYSTEM AND SENSE ORGANS

Objectives

At the end of this lecture you should be able to:

• Make a general diagrammatic representation of the insect nervous system
• List at least six different types of insect sense organs.
• Give a brief account of the insect compound eye and ocelli

13.1: Introduction

The insect nervous system is basically composed of a brain, a suboesophageal ganglion and a ventral nerve cord. The brain is composed of a protocerebrum, and a tritocerebrum. The various types of insect sense organs are thermoreceptors, chemoreceptors, chordotonal organs, campaniform sensillae.

In addition auditory receptors, called tympanal organs and are found in grasshoppers, crickets, and cicadas. The visual receptors of an insect are the compound eyes and the ocelli. Each compound eye is made up of several visual organs (facets) called ommatidia.

13.2: The C.N.S.

The insect nervous system is basically like that of other arthropods. The generalized insect nervous system consists of the brain, a suboesophageal ganglion a ventral nerve cord with paired ganglia. One to three pairs of thoracic ganglia are found in each thoracic segment and five to eight pairs of abdominal ganglia are found in the abdomen as shown on Fig. 13.1 below.
The brain is composed of a protocerebrum, and a tritocerebrum. This mass also contains secretory cells, which produce endocrine materials.

The ventral nerve cord forms a chain of median segmental ganglia. The subesophageal ganglion is composed of three pairs of fused ganglia, which control the mouthparts, the salivary glands, and some of the cervical muscles. The brain is connected to the subesophageal ganglion by a connective known as the circumoesophageal connectives.

13.3: Insect sense organs

Sense organs, other than eyes and ocelli, are scattered over the body but are especially numerous on the appendages. The various types of sense organs are described below:

13.3.1: Thermoreceptors
Thermoreceptors are mounted on peg-like structures (olfaction) or on hairs (contact chemoreception), and the endings of the receptor cells pass to the surface of the cuticle through fine canals.

13.3.2: Chemoreceptors
Chemoreceptors are especially abundant on the antennae, legs, and mouth parts. Perception of chemicals is important in many aspects of the life of insects. Smell may assist in finding food, or a mate, while contact chemoreception may be of importance in the final recognition of food, oviposition site or mate. Chemoreceptors that detect smell are mounted on peg like structures. They are also found on hairs on the insect body where they function as contact chemoreceptors. The endings of the receptor cells pass through canals to the surface of the cuticle.

13.3.3: Chordotonal organs
Chordotonal organs are composed of one or more units called scolopidia. Each scolopidium is a structure consisting of a cilium-like sensory process, which is covered and surrounded cell. The top of the scolopidium is attached to the underside of the integument. Chordotonal organs are important proprioceptors and are typically located in joints and wing bases, although they may be found elsewhere. There are a number of specialized or modified chordotonal organs. Contact, pressure, vibrations, and changes in cuticular tension as a consequence of movement are detected by tactile hairs and chordotonal organs.

13.3.4: Campaniform sensillae
Campaniform sensillae, which are common in joints, have the sensory process in contact with a thin layer of cuticle in the shape of a dome or plate, which is altered by tension changes in the surrounding skeleton.

13.3.5: Auditory receptors
Auditory receptors, called tympanal organs and are found in grasshoppers, crickets, and cicadas, which also have sound-producing organs. Tympanal organs develop from the fusion of parts of a tracheal dilation and the body wall. The scolopidia are attached to the tympanum. An air sac beneath the tympanum permits vibrations, which excite the attached receptors.

13.3.6: Visual receptors

The visual receptors are the compound eyes and the ocelli. There are usually three found on the anterior dorsal surface of the head. Compound eyes are laterally situated on the head. Each compound eye is made up of several visual organs (facets) called ommatidia.
The surface of each ommatidium is a hexagonal lens, below which is a second, conical lens. Light entering the ommatidium is focused by these lenses down a central structure, called the rhabdom, where an inverted image forms on the light-sensitive retinular cells. Optic nerve fibers transmit information from each rhabdom separately to the brain, where it is combined to form a single image of the outside world. The number of facets is greatest in flying insects, which depend on vision for feeding. Extreme reduction of facets is found in certain parasitic and caves-dwelling insects. The facets are larger in nocturnal than in diurnal insects, and in some crepuscular flying neuropterans the eye are divided into upper small-faceted, and lower larger-faceted areas. They function in orientation and in some way appear to have a general stimulatory effect on the nervous system, enhancing the reception of stimuli by other sensory structures.

**Summary**

- The insect nervous system is basically composed of a brain a suboesophageal ganglion and a ventral nerve cord
- The brain is composed of a protecerebrum, and a tritocerebrum
- The various types of insect sense organs are thermoreceptors, chemoreceptors, chordotonal organs, campaniform sensillae
- Auditory receptors, called tympanal organs and are found in grasshoppers, crickets, and cicadas
- The visual receptors of an insect are the compound eyes and the ocelli
- Each compound eye is made up of several visual organs (facets) called ommatidia

**LECTURE 14: REPRODUCTION AND THE REPRODUCTIVE SYSTEM**

**Objectives**

At the end of this lecture you should be able to:

- Differentiate a male from a female insect from a general dissection
- Draw and name all the parts of a male and female insect, particularly the grasshopper
- Write short notes reproductive structures such as the ovipositor, spermatheca

**14.1: Introduction**

The sexes are always separate in insects, and fertilization is internal. Most are oviparous, but a few are viviparous and bring forth young alive. Parthenogenesis occurs in some insects such as Aphids, gall wasps and others. In a few (for example Master sp., a type of a fly) a process called paedogenesis occurs. This involves parthenogenesis by larval stages rather than by the adults. Many larvae are produced, some of which pupate to become male and female adults.

Methods of attracting the opposite sex are often complex in insects. Some, like the female moth, give off a scent that can be detected by males. Fireflies use flashes of light for this purpose, whereas many insects find opposite sexes by sounds. In most insects copulation occurs sperm is deposited in the female vagina and fertilization is internal. In some orders sperm encased in spermatophores can be transferred to the female during copulation or may be deposited on a substratum to be found and picked up by the female who places it in her vagina.

Insects usually lay a large number of eggs. The queen bee for instance may lay more than a million eggs in her lifetime. Insects reveal marvelous instincts in laying their eggs. Butterflies will lay their eggs only on a particular kind of plant on which the caterpillar feeds. Many, however, drop their well protected eggs in the right environment.

**14.2: The male system**

The male reproductive system (See figure 14.1) consists of a pair of testis, which connect with paired seminal vesicle and a median ejaculatory duct. In most insects there are also a number of accessory glands, which open into the vasa deferentia or ejaculatory duct.
14.2.1: Testis

The testis lie above or below the gut in the abdomen and are often close to the midline. Each testis usually consists of a number of tubes or follicle, which contain spermatozoa. The number of follicles vary with insect groups. The follicle empty into a lateral duct, the vas deferens, which join the duct from the other side to form a common ejaculatory duct. A section of each vas deferens is usually enlarged into a seminal vesicle where sperm are stored. Accessory glands are concerned with spermatophore formation and sperm maintenance. Accessory glands secrete the seminal fluid for these purposes. Glands associated with the ejaculatory duct are the hyaline, white and opalescent glands, which vary in number depending on insect groups.

14.2.2: Vas deferens

The vas deferens

From each testis follicle a fine and short vas deferens connects with the main vas deferens. The vas deferens runs backwards to lead into the distal end of the ejaculatory duct and often they are dilated to form the seminal vesicle.

14.2.3: Ejaculatory duct

The ejaculatory duct leads into a structure called the aedagus. The aedagus is lined with muscles. The aedagus vary with insect groups.

14.3: The insect female reproductive system

The female reproductive system (see figure 14.2) consists of a pair of ovaries, which connect with a pair of lateral duct called oviducts. These join to form a median oviduct which open posteriorly into a genital chamber. In some insect groups the genital chamber is closed to form a tube the vagina, the vagina is further developed to form the bursa copulatrix, which is the part that receives the penis. Opening from the genital chamber is a spermatheca whose function is to store sperms after copulation. A pair of accessory glands also open into the genital chamber or vagina.

Fig.14.2: Insect female reproductive system
14.3.1: Ovaries

The ovaries lie in the abdomen lateral to the gut. Each consists of a number of egg tubes, the ovarioles comparable with the follicles in the testis. The number of ovarioles is usually constant within a species. Distally each ovariole is produced into a long terminal filament. The filaments from each ovary join to form a suspensory ligament. The ligaments of the two merge into a median ligament. The ligaments are inserted into the body wall so that the developing ovaries are suspended in the body cavity. Proximally the ovariole narrows to a fine duct, the pedicel, which connects with the oviduct.

14.3.2: Oviducts

Oviducts are tubes, which join to form the median oviduct. The median oviduct opens into the gonopore or the genital chamber. When the genital chamber is a continuation of the oviduct it is called the vagina and the opening of the vagina is called the vulva. The vulva leads to the bursa copularix.

14.3.3: Accessory glands

The Accessory glands usually arise from the genital chamber. They produce a substance for attaching the eggs to the substratum during egg laying (ovipositor). In some insects the spermtheca produce poison for defense. They may also serve to lubricate the ovipositor. In some ants these glands produce Pheromones used in marking trails.

14.3.4: Spermtheca

A Spermtheca is present in most insects with numbers varying from one to three. In some insects the spermtheca opens into the oviduct whereas in others it opens into the genital chamber. It consists of a storage pouch. Its glandular cells produce secretions, which provide nutrients to sperms.

**Summary**

- The male reproductive system consists of a pair of testis, the vas deferens, the ejaculatory duct, the accessory glands and the aedagus
- Each testis usually consists of a number of tubes or follicle which contain spermatozoa
- A section of each vas deferens is usually enlarged into a seminal vesicle where sperm are stored.
- Accessory glands of the male insect are concerned with spermatophore formation and sperm maintenance. Accessory glands also secrete the seminal fluid for these purposes.

- The female reproductive system consists of a pair of ovaries
- Each ovary consists of a number of egg tubes, the ovarioles
The female insect accessory glands usually arise from the genital chamber. They produce a substance for attaching the eggs to the substratum during egg laying (ovipositor). They may also serve to lubricate the ovipositor. In some ants these glands produce pheromones used in marking trails.

A spermtheca is present in most female insects and is a storage pouch for sperms after copulation. Its glandular cells produce secretions, which provide nutrients to sperms. In some insects the spermtheca they produce poison for defense.

ACTIVITY 14.1

1. Illustrate the insect male reproductive system
2. Define spermtheca
3. Define ovipositor
4. List two functions of accessory glands

LECTURE 15: INSECT GROWTH AND DEVELOPMENT

Objectives
At the end of this lecture you should be able to:

Define Ametabolous, Hemimetabolous and Holometabolous life cycle.

Identify different types of immature stages of insects.

Describe the terms; heteromorphosis, naiads, ecdysis, instar, nymph, eucephalus, hemicephalus, and paurametabola, endopterygote, exopterygote

Discuss the significance of insect metamorphosis.

Define naiads, heteromorphosis, ecdysis, instar,

Differentiate hemimetabola from holometabola

Describe three types of pupae.

State forms of development traits such as paedomorphosis, parthenogenesis and hermaphroditism.

15.1: Introduction

Insects reproduce sexually. Usually the opposite sexes mate and eggs are reproduced. Most insect eggs hatch outside the body. Insects, which lay eggs, which hatch outside the body, are said to be oviparous. Insects which protrude larvae are termed larviparous e.g. the tsetse flies. A few species retain the eggs inside the body until they hatch and give birth to young, these are the viviparous insects.

After the immature stages of the insect leave the egg, it undergoes a change of form or metamorphosis until the adult stage is reached. To accomplish this change of form and to grow, the insect must shed its hard exoskeleton. This shedding process is called ecdysis or moulting. The stages between the molts are referred to as instars. Most weight gain (sometimes > 90%) occurs during the last one or two instars. In general, neither eggs, pupae, nor adults grow in size; all growth occurs during the larval or nymphal stages. Insects may be placed into three groups with respect to their type of metamorphosis. These groups are:

Ø Ametabola
15.2: Ametabola
The Ametabolous insects are said to have no metamorphosis because the young do not really change form as they mature. The immature forms look very much like the adults but are smaller and sexually immature. These insects lack wings even as adults. The stages in the life cycle of an ametabolous insects are the egg, the young and adult. A typical example of an Ametabolous insect is the silverfish (Order Thysanura).

15.3: Hemimetabola
The Hemimetabolous insects are said to have incomplete or gradual metamorphosis. Eggs hatch into nymphs which are similar to adults but lack fully developed wings. Nymphs may occupy the same habitats or different habitats as the adults. There are generally several nymphal stages (instars), each progressively larger and requiring a molt, or shed of the outer skin, between each stage. A typical example of an hemimetabolous insect is the grasshopper (Order Orthoptera).

15.4: Holometabola
These are the insects that undergo complete metamorphosis comprising of four distinct stages as follows: egg, larva, pupa and adult. Complete metamorphosis is typical of beetles, flies, moths, and wasps. The immatures of these latter species do not resemble the adults, may occupy different habitats, and feed on different hosts. Some moth and wasp larvae weave a silken shell (cocoon) to protect the pupal stage; in flies, the last larval skin becomes a puparium that protects the pupal stage. There are generally several larval stages (instars), each progressively larger and requiring a molt, or shed of the outer skin, between each stage.

15.5: Heteromorphosis
When successive larva forms are quite different in form the development is called Heteromorphosis or hyper metamorphosis. Heteromorphosis is common in predaceous and parasitic insects in which a change in habitat occurs during the course of larval development. Two types of heteromorphosis occur, one in which the eggs are laid in the open and the first instar larva searches for the host, and a second in which the eggs are laid in or on the host.

15.6: Types of insect larvae
On the basis of general appearance, insect larvae can be grouped into broad categories:

1. Nymph is the term applied to young hemimetabolous insects. They differ from holometabolous larvae in wing development. Their wings develop as external buds. They become larger at each molt. They finally enlarge into adult wings in the last molt to adult.
2. Larva is the term applied to the immature stage of holometabolous insect, which differ in structure and habits from their adults. Their wings develop in invaginations beneath the cuticle, so are not visible externally. The invaginations are finally everted to make wings visible. This happens when larval forms molts to a pupa.

There are many different larval forms among holometabolous insects, which may be classified into the following types:

(a) **Protopod larvae.** These are primitive parasitic larvae with barely incipient limb-buds and with no segmentation of the abdomen. They are found in some parasitic hymenoptera.

(b) **Polypod or Eruciform** larvae. These are the typical caterpillar with six legs on the thorax and a number of prolegs on the abdomen. They are found in Lepidoptera and sawflies.

(c) **Oligopod or Campodeiform** larvae. These are usually predatory and therefore have efficient sense organs and long legs but no prolegs. They have six thoracic legs with well-developed head capsule. The mouthparts are similar to the adult form. They are common among beetles.

(d) **Scarabaeiform** larvae. These are fat with poorly sclerotized thorax and abdomen. They are short legged inactive, burrowing in wood or soil. They are found in beetles such as the rhinoceros beetle.

(e) **Apodous** larvae. These are legless larvae with segmented bodies with a minute head and a few sense organs. They are either fed by other members of the colony as in bees, or the eggs are laid in suitable food material such as dung. These are common among Diptera e.g. houseflies. And some parasitic hymenoptera.

**Eucephalus**- with well sclerotized head capsule as in Neuroptera.

**Hemicephalous** - with reduced head capsule. Head can be retracted within the thorax as in horseflies.

**Acephalous** - without head capsule as in some parasitic Hymenoptera.
15.7: Types of pupae

(a) Exarate pupae

In some pupae the appendages are free from the body. This condition is known as exarate.

(b) Obtect pupae

In most pupae the appendages are glued down to the body by a secretion produced at the larva/pupa molt. This is the obtect condition.

15.8: Significance of insect metamorphosis

Insects are cold-blooded, so that the rate at which they develop is mostly dependent on the temperature of their environment. Cooler temperatures result in slowed growth; higher temperatures speed up the growth process. If a season is hot, more generations may occur than during a cool season. A better understanding of how insects grow and develop has contributed greatly to their management. For example, knowledge of the hormonal control of insect metamorphosis led to the development of a new class of insecticides called insect growth regulators (IGR). The insect growth regulators are very selective in the insects they affect. Based on information about insect growth rates relative to temperature, computer models can be used to predict when insects will be most abundant during the growing season and, consequently, when crops are most at risk.

Summary

- Most insects hatch from eggs, others are ovoviviparous or viviparous, and all undergo a series of molts as they develop and grow in size.
- Moulting is a process by which the individual escapes the confines of the exoskeleton in order to increase in size, then grows a new outer covering.
- In most types of insects, the young, called nymphs or larvae.
- The Ametabolous insects are said to have no metamorphosis because the young do not really change form as they mature.
- Nymphs are basically similar in form to the adults (an example is the grasshopper), though wings are not developed until the adult stage. This is called incomplete metamorphosis. Insect that undergo incomplete metamorphosis are termed hemimetabolous. (Exopterygota)
- Exopterygota undergo gradual metamorphosis.
- Insects that undergo complete metamorphosis are termed holometabolous (Enopterygota). Enodpterygota undergo complete metamorphosis, and includes many of the most successful insect groups.
- In holometabolous insects, an egg hatches to produce a larva, which is generally worm-like in form, and can be divided into five different forms; eruciform (caterpillar-like), scarabaeiform (grublike), campodeiform (elongated, flattened, and active), elateriform (wireworm-like) and vermiform (maggot-like). The larva grows and eventually becomes a pupa, a stage sealed within a cocoon or chrysalis in some species.
- There are three types of pupae; obtect, exarate and coarctate. In the pupal stage, the insect undergoes considerable change in form to emerge as an adult, or imago.
- Butterflies are an example of an insect that undergoes complete metamorphosis.
- Some insects have even evolved hypermetamorphosis. Other development traits are haplodiploidy, polymorphism, paedomorphosis (metathely and prothely), sexual dimorphism, parthenogenesis and more rarely hermaphroditism.

Activity 15.1

1. Distinguish with named example, three types of insect metamorphosis
2. List and draw at least five different types of insect larvae

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3 and name two types of insect pupae
4. Define these terms with specific examples; instar, ecdysis, naiad, heteromorphosis

LECTURE 16: RECOGNITION OF INSECT ORDERS PART.1

This lecture will demonstrate insect abundance and diversity. The insects have been classified into their respective orders according to some common features (similarities) unique to each order. Similarities in certain structures is a reflection of evolutionary relationships or phylogeny among insect groups. The lecture will help us identify commonly encountered insects in our houses, gardens, on our animals and crops and sometimes even on our bodies! This basic insect taxonomy should serve as the first step to more complex insect taxonomy.

The insect orders we shall examine in this particular lecture include the following:-

Anoplura (sucking lice), Coleoptera (beetles and weevils), Collembola (springtails), Dictyoptera (cockroaches and mantids), Diplura, Diptera (true flies), Embioptera (Webspinners), Ephemeroptera (mayflies), Hemiptera (bugs) Homoptera (cicadas, hoppers, whiteflies, aphids), Hymenoptera (ants, bees, wasps, saw flies), Isoptera (termites / white ants), Lepidoptera (butterflies, moths),

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OBJECTIVES

At the end of this lecture you should be able to:-

1. List several insect orders to depict their great diversity.

2. Relate the diversity of insects to their habits.

3. Identify any insects up to the level of order.

4. Use both pictorial and dichotomous key to identify insects to orders.

16.1: Order Anoplura – sucking lice

Sucking lice are pests that feed on the blood of their host. They attack humans and animals and their bites are often very irritating. Each species usually attacks one or a few related species of hosts, and generally lives on a particular part of the host's body. Eggs are usually attached to hair of the host; egg of the body louse are laid on clothing. Sucking lice spend their life on their host and do not survive long away from it.

They are small, usually less than 4mm in length, flattened and wingless. Their mouthparts are made for sucking and they withdraw into the head when not in use. The antennae are short, threadlike or tapering distally, 3 to 5 segmented. The head is small and nearly always narrower than the thorax.

There are two subspecies of the common human louse: Pediculus humanus capitis, the head louse, and P. humanus humanus, the body louse. The body louse is an important carrier of epidemic typhus; other louse-borne human diseases are trench fever and relapsing fever.

Fig 16.1a: A Louse, Dorsal
16.2: Order Coleoptera - the beetles and weevils

The Coleoptera is the largest order of insects; it contains about forty percent of all known species. It includes the beetles and weevils. Among the more than 250,000 species are many of the largest and most beautiful of all insects. Some have brilliant metallic colors, showy patterns or striking forms. Beetles can usually be recognized by their two pairs of wings. The first pair is modified into horny covers (elytra) that hide the rear pair and most of the abdomen. They usually meet down the back in a straight line. Coleoptera occur in nearly all climates. They may be divided into four groups: the first three, the Archostemata, the Adephaga, and the Myxophaga, contain relatively few families; the majority of beetles are placed in the fourth group, the Polyphaga.

16.3: Order Collembola - the springtail

The springtail are small, primitive wingless insects. Although crawling is their usual method of locomotion, they have a jumping apparatus at the end of their abdomen. They range in length from 1 to 10 mm (0.04 to 0.4 inches), called a furcula. It permits some mighty leaps, which is the origin of the common name "springtail." There are about 3,500 species. Springtail are found in all types of soil and leaf litter throughout the world from Antarctica to the Arctic, and are one of the most widely distributed insects. Certain springtails known as snow fleas are active at near-freezing temperatures and may appear in large numbers on snow surfaces. Springtails live in soil and on water and feed on decaying vegetable matter, sometimes damaging garden crops and mushrooms. Fossil springtails are among the oldest insect fossils known.

16.4: Insect order Dermaptera: earwigs
Characteristics

Earwigs are a distinctive group of insects of small to medium size, ranging from 5 to 50 millimeters in length. Earwigs are sometimes confused with Staphylinid beetles, but can be distinguished from the latter by the presence of pincer-like cerci, which Staphylinid beetles lack. Earwigs are mostly dark coloured (brown to black) and can be recognised by the following features:

- Flattened elongated body
- Heavily sclerotised pincer-like cerci. Females have straight cerci with a inward pointing tip and males have curved cerci
- 2 pairs of wings. The forewings are short and protectively hardened. The hind wings are membranous and folded in a fan-like way underneath the forewings when not in use. Some species are also wingless
- Chewing (mandibulate) mouthparts
- Moderately long antennae

The LABIDURIDAE family of earwigs consists of relatively primitive species that are predominantly a red-brown color and range from 10 to 45 millimeters in length. Members of this family are found all over Australia. Labidura truncata is by far the commonest species, particularly in sandy habitats. It is approximately 35 millimeters long and dull brown with straw colored markings. The male have long slender pincers with a distinctive tooth near the middle of the inner edge.

16.5: Order Dictyoptera

Dictyoptera are described as variably sized insects with generally filiform (long and thin) antennae usually composed of many small segments. They have mandibulate or biting mouthparts and legs that are roughly similar (except the Mantids which have raptorial forelegs), most have 5 tarsi. Many species are winged and the forewings are generally hardened into a tegmina while the hind wings are often fan-like, the wing buds of the nymphs do not undergo reversal.

16.6: Order Diplura: two pronged bristle tails
Apterygote (primarily flightless) insects with entognathous mouthparts, many segmented antennae, ten large abdominal segments followed by one small abdominal segment which carries the variably formed paired cerci. They have no eyes at all.

The Diplura or two pronged bristle-tails (from diplos = double and oura = a tail) are another group of soil and leaf-litter insects of ancient origin, they are mostly small (the largest being about 5cm long), often white in color and occur all over the world. There are around 800 known species. The cerci or (tails) are often long, but may be short and stubby or even pincer like. The Diplura

Apterygote (primarily flightless) insects with entognathous mouth-parts, many segmented antennae, ten large abdominal segments followed by one small abdominal segment which carries the variably formed paired cerci. They have no eyes at all. The name Diplura, derived from the Greek words "diplo-" meaning two and "ura-" meaning tails, refers to the large cerci at the rear of the abdomen.

The Diplura or two pronged bristle-tails (from diplos = double and oura = a tail) are another group of soil and leaf-litter insects of ancient origin, they are mostly small (the largest being about 5cm long), often white in colour and occur all over the world. There are around 800 known species 11 of which occur in Great Britain and 70 in North America. The cerci or (tails) are often long, but may be short and stubby or even pincer like.

Life History & Ecology:

These small, eyeless arthropods are considered to be among the most primitive of all hexapods. They have a pair of long, beaded antennae on the head and a pair of segmented sensory structures (cerci) at the rear. In one common family (Japygidae), these cerci are developed into strong pincers.

Diplura are tiny, cryptozoic animals that live in moist soil, leaf litter, or humus. They have small, eversible vesicles on the ventral side of most abdominal segments that seem to help regulate the body's water balance, perhaps by absorbing moisture from the environment.

Most Diplura are predators; their diet probably includes a wide variety of other soil-dwellers, including collembola, mites, symphyla, insect larvae, and even other diplurans. They may also survive on vegetable debris and fungal mycelia, but most species seem to prefer animal prey.

Classification: Ametabola lacking metamorphosis eggs hatch into young, which are smaller than adults, but similar in appearance. Apterygota primitively wingless

Physical Features for adults and immatures: Compound eyes absent, Antennae longer than head, with 10 or more bead-like segments, Abdomen with 10 visible segments, Cerci present, long and slender, Tarsi one-segmented or forceps-like in appearance, Short, lateral styli and eversible vesicles present on most of the first 7 abdominal segments

Economic Importance:

Diplurans are common inhabitants of forest leaf litter. They are part of the community of decomposers that help break down and recycle organic nutrients. None of the Diplura are considered pests.

Fact File:

The sexes are separate and fertilization is external. Males produce sperm packets (spermatophores) and glue them to the substrate on the end of little stalks. Females use their genital opening to gather spermatophores and then lay their eggs on little stalks inside a crevice or small cavity in the ground.

Male Diplura produce large numbers of spermatophores up to 200 per week. This large number is probably necessary because sperm only remain viable in the spermatophore for about two days.

The cerci of some diplurans are designed to break off near the base if they are mishandled. This spontaneous autotomy is probably an adaptation for avoiding predation. A similar adaptation is found in the legs of some walking sticks and the tails of some lizards.

Diplura and some walking sticks (Phasmatodea) are the only terrestrial arthropods known to be able to regenerate lost body parts. Legs, antennae, and cerci can be regenerated over the course of several molts. Some crustaceans (e.g. crabs and lobsters) can regenerate missing legs or claws.

16.7: Insect Order Diptera – true flies
Although many winged insects are commonly called "flies," the name is strictly applicable only to members of the Diptera. It is one of the largest insect orders and contains over 85,000 species; all are relatively small and have soft bodies. Mouthparts are of the sucking type, but there is great variation. Diptera have one pair of wings. Some, like the blood-sucking tsetse flies, are serious pests. Flies are beneficial as scavengers and predators or other insect pests.

Diptera are divided into three large groups: Nematocera (mosquitoes, crane flies, midges, and gnats); the Brachycera (horse flies, robber flies, and bee flies); and Cyclorrhapha (houseflies, blow flies, flesh flies, botflies, stable flies, camel flies, horse flies etc. that breed in vegetable or animal material, both living and dead.)

16.8: Order Embioptera – Webspinners.

Small, slender, soft bodied insects with large heads and eyes. They feed on plants and live in silken tunnels, which they weave ahead of themselves to create routes. They are gregarious and live in large colonies. They are found in the tropics and semi-tropics. Metamorphosis is gradual.

16.10: Order Hemiptera or Heteropteran

These are "the true bugs." They are found worldwide, in climates from tropical to arctic. There are 30,000 known species; most live in tropical areas.

Heteropterans range in size from under one millimeter (0.04 inch) to more than 100 mm. They are distinguished from other insects by the presence of a pair of simple eyes in front of and above the compound eyes, a hardened gula (the area below the mouthparts), and an "X" formed on the back by the overlapped wings. They live chiefly on plant or animal juices. Heteropterans are important to man in several ways. Some, such as plant bugs (Miridae) and stinkbugs (Pentatomidae), may damage crops while feeding. On the other hand, certain predatory heteropterans are used to control infestations of other crop-damaging insects. Some, like the bedbugs, are biting pests, and still other may serve as carriers of various diseases. The order is divided into three suborders. Families comprise of the aquatic Hydrocorisae Water Bug (giant water bugs, water boatmen, water scorpions, and backswimmers )and terrestrial Geocorisae (bedbugs, stinkbugs, assassin bugs, lace bugs, fire bugs, and plant bugs)

Fig. 16.10a : Stink Bug  
Fig. 16.10b : Bed bug  
Fig. 16.10c : left, water bug; right, assassin bug

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16.11: Order Homoptera - cicadas, hoppers, whiteflies, aphids

The Homoptera are a large group of sucking insects. There are more than 32,000 species and there is great diversity in body size. All are plant feeders and have mouth parts adapted for sucking plant sap from trees and plants. They can cause injury and destroy valuable food crops such as fruit trees and grain crops. Some carry plant diseases, but a few provide secretion or other products that are beneficial and have commercial value.

The mouth parts are adapted for sucking; the beak arises from the back of head, wings, when present, number four, the front wings have uniform structure, either membranous or slightly thickened; wings at rest usually held roof-like over body; male scale insects with only 1 pair of wings; ocelli present or absent; compound eyes usually well developed. Most members of the Homoptera fall into one of two large groups: The Auchenorrhyncha, which consists of the cicadas, treehoppers, froghoppers or spittlebugs, leafhoppers, and planthoppers or fulgorids; The Sternorrhyncha, which includes aphids or plant lice, phylloxerans, coccids, scales, whiteflies, and mealy bugs.

16.12: Order Hymenoptera - ants, bees, wasps, sawflies

Two pairs of membranous wings; venation often much reduced; the hind wings are smaller and connected to fore wings by a row of hooklets; the mouthparts are primarily of biting type but often adapted for sucking fluids; the abdomen usually constricted at the base (except sawflies) with first segment fused to metathorax; ovipositor always present and modified for sawing, piercing or stinging; larvae usually legless with distinct head. The Hymenoptera are divided into two suborders: Symphyta (mainly sawflies and hornets) and Apocrita (wasps, ants, bees, and most parasitic forms)

16.13: Insect Order Isoptera - termites / white ants
Termites are well known both for their destruction of human property and for their construction of huge mounds or ‘termitaria’ which allow them to have a great degree of control over the temperature and humidity of the environment they live in. They are common in the tropics and occur in most warm habitats as well. They are often called ‘white ants’ because the majority of them are white and small and live in large colonies much like ants. They are not actually closely related to the ants at all but are closely related to the Cockroaches. The most primitive Termite known is *Mastotermes darwiniensis* from northern Australia. *Mastotermes darwiniensis* lives in the soil in nests consisting of up to 1,000,000 individuals, has very catholic tastes (will eat almost anything) and has been described as the most destructive insect in Northern Australia. Its workers are very similar to nymphs of the Cockroach *Cryptocercus punctulatus*. Some of the most advanced species are the *Macrotermiteinae*, which grow fungi for food (*Termitomyces*) inside their nests on piles of faecal pellets. The oldest known Termites are fossils of *Cretotermes carpenteri* from the Cretaceous. The sterile workers live for 2-4 years while primary sexual live for at least 20 and perhaps 50 years.

They are described as hemimetabolous, medium sized polymorphic (having more than one form) social insects. They have biting mouthparts, short cerci and moniliform (appearing as if composed of a series of beads) antennae comprising 9 to 30 segments. The alate forms (winged primary reproductives) have four almost equal wings and compound eyes; however the sterile workers and the secondary reproductives have no or greatly reduced compound eyes some forms have two ocelli.

16.14: Order Lepidoptera - butterflies, moths

Lepidoptera are Holometabolous insects (insects which have larvae that look nothing like the adults/imagos and having a complete metamorphosis with a pupal stage). They possess two pairs of membranous wings with few cross veins, (though these may be absent in the females of some moths). The mandibles are present in the larvae but nearly always absent in the imagos/adults in whom the principal mouth parts are a sucking tube or proboscis formed from the maxillae which is held curled up in a spiral under the head when not in use (in a number of species of Moths the mouthparts are all degenerate in the imagos and these do not feed at all. The antennae are variable in length and may be quite complicated in some male moths. The imagos have two large compound eyes with as many as 6,000 ommatidia and two ocelli, while the larva often have simple ocelli. The wings and body of the imagos are covered in scales and the body of the larva are generally covered in hairs (though these may be very fine and short). The salivary glands of the larvae have become modified to form the silk glands. The larvae are 'eruciform' (which means they look like a caterpillar) and in most cases have 13 body segments with three pairs of jointed legs on the first three segments, (which are roughly equivalent to a thorax in the imago). Segments 3 to 6 of the abdomen (6,7,8,9 counting back from the head) each have a pair of unjointed pro- or false-legs, these end in a contractile pad surrounded by a ring of minute hooks; there is also a pair of unjointed claspers on the final segment.

16.15: Order Mallophaga- biting lice

The Mallophaga are described as wingless (Apterous), hemimetabolous (having a simple metamorphosis i.e. no pupa) ectoparasites (living on the outside of their hosts) of mostly birds but also of some mammals, there are about 2,800 species worldwide. The range in size from 0.5 to 10 mm long dorsoventrally flattened with reduced compound eyes and no ocelli. The antennae are 3 to 5 segmented and capitate (with a knob on the end) and retracted into the head in the Amblycera but filiform (thin and linear) in the Ischnocera and may be modified as clasping organs in the male. Their mouthparts are designed for biting and they have no cerci; there is some suggestion that they may have evolved from the Psocoptera (Book and Bark Lice).
In this lecture we have learned the that:

- Evolutionary relationships among insect groups is referred to as or phylogeny
- The class Insecta has two subclasses; namely Apterygota and Pterygota
- Apterygota are the primitive wingless insects that have not evolved from the winged ancestor; they have little or no metamorphosis and they have stylet like abdominal appendages, in addition to the cerci. Orders Protura, Collembola and Thysanura are apterygotaes
- Sub class Pterygota are usually winged and have no abdominal appendages except cerci. and it includes 97% of all insects.
- Sucking and biting lice and bed bugs are pests that feed on the blood of their host. The body louse is an important carrier of epidemic typhus; other louse-borne human diseases are trench fever and relapsing fever
- The weevils and beetles (Coleoptera) form the largest order of insects and can be recognized by the hard wing called elytra.
- Diptera have one pair of wings. Some, like the blood-sucking mosquitoes and tse-tse flies, are serious pests. Flies are however beneficial as scavengers and predators of other insect pests.
- Ants, bees, wasps (Hymenoptera) have a constricted abdomen, while butterflies and moths (Lepidoptera) can be recognized by the colourful patterns in their wings

ACTIVITY 16.1
1. Define these terms; apterygota, pterygota, exopterygota and endopterygota
2. classify the following into orders; butterfly, sucking lice, biting lice, beetle, ant, bees, housefly, aphid, cockroach, assassin bug, termite, bristle tails
3. Name three insect orders that are parasites of mammals.
4. Name the insect order whose members have only one pair of wings.

LECTURE 17: INSECT ORDERS PART

Objectives

Relate the diversity of insects to their habit

17.1: Introduction

This lecture is essentially a continuation of the previous lecture but we shall examine different types of insect orders from those you that you have studied.

This lecture will demonstrate insect abundance and diversity. The insects have been classified into their respective orders according to some common features unique to each order. Similarities in certain structures is a reflection of evolutionary relationships or phylogeny among insect groups. The lecture will help us identify commonly encountered insects in our houses, gardens, on our animals and crops and sometimes even on our bodies! This basic insect taxonomy should serve as the first step to more complex insect taxonomy.

Mecoptera- scorpion flies, Neuroptera- lacewings, Odonata, dragonflies
Orthoptera, grasshoppers and crickets, Phasmida stick insects, Plecoptera, stoneflies, Protura, Psocoptera book lice or psocids, Siphonaptera fleas

Siphunculata sucking lice, Strepsiptera stylops, Thysanoptera thrips

Thysanura silverfish, Trichoptera caddisflies and

Zoraptera

17.2: Order Mecoptera- scorpion flies

Mecoptera are small to medium sized slender insects with long filiform antennae. The head is extended into a deflexed rostrum or beak with biting mouthparts at its end and is not broader than the front of the thorax, the eyes are prominent and semi-globose. The legs are long and slender, as are the 2 pairs of nearly equal wings, which are also membranous and clear with various dark patterns. The larva are generally eruciform (like a caterpillar), but may be modified Scarabaeiform (grub like, with a well developed head, a thick cylindrical body and 3 pairs of thoracic legs, but no prolegs) i.e. Boride and Panorpidae, or campodeiform (elongate and flattened with well developed legs and antennae) as in the Nanochoristidae. They have biting mouthparts and 3 pairs of thoracic legs. The pupa is exarate (having its appendages i.e. legs antennae etc. free outside of the main body of the pupa) and dectitious.

Fig. 17.1a: Scorpion fly

Fig.17.1b:Scorpion fly with wings spread out

17.3: Order Neuroptera- lacewings

Neuroptera are soft-bodied insects of variable size usually with longish antennae. They have biting and chewing mouthparts both as larvae and as adults, though some of the adults do not feed. They generally have 2 pairs of wings, of which the hind pair are usually larger to some extent. The wings are normally held tent-like over their abdomen when not in flight. They have no cerci. They have ten segments to their abdomen and 5 to their tarsi.

They have large compound eyes. Their legs are all similar, except in the mantispidae, which have raptorial grasping forelegs. Those adults who feed do so on dead insects, nectar and other liquids. The larvae are all carnivorous. Many of the adults are relatively weak flyers and the larvae of some species attach the empty skins of their prey to backs as a disguise.

Fig 17.2b : Lace wing on a plant
17.4: Order Odonata - dragonflies

Dragonflies have two pairs of almost equally sized long thin membranous wings; both pairs of wings usually have a stigma (a dark or colored patch near the middle of the leading edge) and a mass of cross veins giving them the appearance of being a mesh. Unlike most insects, which either flap both pairs of wings in unison (i.e. Bees and Butterflies), or only flap the hind pair (i.e. Beetles), or only have one pair (i.e. Flies), Dragonflies can flap or beat their wings independently. This means the front wings can be going down while the back ones are coming up. You can see this happening if you watch closely. Dragonflies are excellent fliers, particularly the Anisopterans and can loop-the-loop, hover and fly backwards quite easily. It is not unusual for the larger species to reach 30kph and the Australian Austrophlebia sp. has been clocked in at an impressive 58kph or 36 mph for short bursts. They flap their wings relatively slowly though, at less than 30 beats per second. Compare this with 200 bps for a hoverfly or 300 bps for a honeybee.

![Image of dragonfly](image)

**Question** Where do you normally encounter dragon flies?

17.6: Order Phasmida - stick insects

Phasmida are hemimetabolous and generally elongate, though some forms (Leaf-Insects) are broad and flattened. Some forms are apterous (winged) though often only the male flies. They have biting and chewing mouthparts and are all phytophagous (leaf-eating). They all posses compound eyes and some of the winged forms possess 2 ocelli. Their antennae are generally filiform ranging from 8 to over 100 segments and their cerci are short. They are often adorned with numerous spines and other protuberances.

17.7: Order Plecoptera - stoneflies

There are about 2 000 named species all with aquatic larva, most of whom live only in cool waters, generally running streams or lakes with a upper temperature limit of 25 degrees C. The adults have little difference in texture between the hind and fore wings, and are rather poor fliers. They also have weak mouth parts, small coxa and generally two long slender cerci.

17.8: Order Protura Protura / Cone heads

The name Protura, derived from the Greek words "proto-" meaning first (or original) and "ura" meaning tail, refers to the lack of advanced or specialized structures at the back of the abdomen.
Life History & Ecology:

Proturans are usually regarded as the most primitive of all hexapods. They have six legs and three body regions (head, thorax, and abdomen), but they lack most of the other physical features that are common to arthropods. Most species are very small (0.5-2.0 mm) and unpigmented. They are always found in moist habitats — usually in the humus and leaf mold of temperate deciduous forests. Both adults and immatures feed on organic matter released by decay.

Proturans do not have eyes or antennae. Head conical, all mouthparts enclosed within the head capsule. Body unpigmented, usually white or ivory in color. The front pair of legs are usually held in front of the body and apparently serve as sense organs. Newly hatched proturans have nine abdominal segments. Each time they molt, another segment is added near the end of the abdomen until they are fully grown (and sexually mature) with 12 abdominal segments. Additional molts may occur during adulthood, but the body does not grow any longer.

Classification

Ametabola lacking metamorphosis. Eggs hatch into young, which are smaller than adults, but similar in appearance. Apterygota primitively wingless.

Economic Importance:

Proturans are primarily inhabitants of forest leaf litter. They are part of the community of decomposers that help break down and recycle organic nutrients. None of these arthropods are considered pests.

Fact File:

- Proturans were first discovered by Antonio Sylvestri in 1907 near Syracuse, New York. He found them in samples of leaf litter he had collected for a post-doctoral project on soil-dwelling invertebrates.
- Proturans do not have eyes or antennae. The front pair of legs are usually held in front of the body and apparently serve as sensory organs.
- Two of the three North American families of Protura lack a tracheal system. All gas exchange occurs through the integument.

With only about 500 species worldwide, Protura is the smallest class in the phylum Arthropoda.

17.10: Insect Order Siphonaptera - fleas

Fleas are small laterally compressed (flattened from side to side) holometabolous (having a complete metamorphosis) insects. They are all apterous (flightless [from a = not, and pteron = wing]). They have no eyes though 2 simple ocelli may be present, their antennae short and stout and their adult mouthparts are adapted for piercing and sucking. The larvae are eruciform and apodous meaning they look like a caterpillar with no legs. The adults are all blood sucking ectoparasites (a parasite which lives on the outside of its host) of mammals and birds, while in general the larvae are detritivores feeding on minute particles of discarded organic matter still adhering to the host, or on the substrate of a commonly used sleeping place or nest. The bodies of both adults and larvae have many backward pointing hairs for holding onto hosts.
17.12. Insect Order Strepsiptera

These are small (1.5 to 4.0 mm long), rather unusual looking insects. They are "endoparasites" (parasites that live inside the bodies of their hosts, as compared with ectoparasites which live on the outside) of solitary bees, solitary wasps and other aculeates as well as various true bugs. The female is mostly flightless and are degenerate in that she has no legs and a body that looks rather like a maggot. The males have only one pair of functional wings, and these are the hind wings, the forewings are greatly reduced to look and function like the halteres of flies. They are not that common and few people other than entomologists have or are likely to see them. Their common name of Stylops becomes an adjective when describing the hosts that are carrying them, hence an insect suffering from parasitism by 'Strepsiptera' is described as being "stylopised". There are about 370 species known throughout the world of which 17 appear in the UK.

Strepsiptera are small endoparasitic insects. The males are free living and have unusual 'flabellate' (with projecting flaps on one side) antennae, biting mouthparts and the fore wings reduced to small club-like appendages. The hind wings are relatively large and leathery with longitudinal but no cross veins. The abdomen is 10 segmented and the aedeagus (the organ used to transfer sperm to the female) is on the 9th sternum. They have no cerci. The females, except in the Mengenillidae, are larviform (look like a larva) and lives entirely within the last larval skin within which she also pupated, inside the body of her host. The head and thorax are united to form a cephalothorax. She also has no antennae or eyes and very reduced mouthparts. In the Mengenillidae the females are free living and have legs eyes and antennae.

17.13: Insect Order Thysanoptera - the thrips

They are described as holometabolous (having a complete metamorphosis even though the nymphs look like small wingless adults) insects with 2 or 3 inactive pupa-like instars. Thrips are "Exopterygotaes. They have asymmetrical mouthparts, having only one (the left) mandible, short 6- to 10-segmented antennae and no cerci. Their wings when present are nearly equal, very thin with little venation and a lot of hairs making a fringe around the edge, these hairs greatly increase the effective size of the wings. Fully winged, brachypterous (with reduced wings) and apterous (wingless) forms may occur in the same species. They have piercing sucking mouthparts.
17.14: Insect Order Thysanura - silverfish

Flightless insects with ectognathous mouth parts (externally visible as compared to entognathous mouth parts of the Diplura, Protura and Collembola which are sunk into the head and thus not immediately visible). They have long filiform antennae with as many as, or more than 30 segments. The abdomen has eleven segments generally ending in three 'tails' consisting of two cerci and a telson. They are commonly represented by the Silverfish and the firebrats often found in houses and bakeries respectively.

17.15: Order Tricoptera

These are small to moderate moth-like insects with bristle-like antennae; mandibles vestigial or absent; wings membranous, hairy, at rest held roof like over the back; larvae aquatic, more or less eruciform, usually living in cases held by means of hooked caudal appendages; pupae exarate with strong mandibles.

17.16: Insect Order Zoraptera

The Zoraptera are a very small order of insects, there are about 30 known species. They are also small in size being less than 3 mm long. They are hemimetabolous, have biting mouthparts, very short, 1 segmented cerci, and 9 segmented antennae. They are generally found under bark or in humus and leaf-litter. They are unusual in that each species comes in 2 different forms, one of which is 'alate' (has wings) and the other is 'apterous', i.e. doesn't have wings. The apterous form is the more common, generally white in color and has no compound eyes or ocelli, whereas the alate forms have both compound eyes and ocelli, and are more pigmented. Though less than 3 mm long an alate Zorapteran can have a total wingspan of about 7 mm. Another interesting thing is that like their relatives the Termites (Isoptera) they can voluntarily shed their wings. Though little is known about the biology of Zorapterans it is known that 2 forms of nymphs occur that equate with the 2 different life forms. They are usually found in rotted timber and or sawdust, well composted leaf-litter and Termites nests. They feed on fungal spores and smaller arthropods. The name Zoraptera comes from the Greek words "zor" meaning pure and "aptera" meaning wingless (they were named before the winged forms were discovered).

summary

- Scorpion flies (Mecoptera) can be recognized by means of the head which is extended into a deflexed rostrum or beak
- Lacewings (Neuroptera) are soft bodied insects that can be easily identified by their lace-like wings
- Dragonflies (Odonata) can flap or beat their wings independently. This means the front wings can be going down while the back ones are coming up. Dragonflies are excellent fliers, particularly the Anisopterans and can loop-the-loop, hover and fly backwards quite easily.
Fleas (Siphonaptera) are small laterally compressed (flattened from side to side). The adults are all blood sucking ectoparasites of mammals and birds. The bodies of both adults and larvae have many backward pointing hairs for holding onto hosts.

Thrips (Thysanoptera) have asymmetrical mouthparts, having only one (the left) mandible, their wings when present are nearly equal, very thin with little venation and a lot of hairs making a fringe around the edge.

Angel flies (Zoraptera) are interesting in that like their relatives the Termites (Isoptera) they can voluntarily shed their wings.

ACTIVITY 17.1

Indicate the Insect order against each insect listed below:

1. Thrips
2. Silverfish
3. Booklice
4. Stylops
5. Stoneflies
6. Cone heads

LECTURE 18: THE SOCIAL INSECTS

OBJECTIVES

At the end of this lecture you should be able to:

- Identify the social insects and discuss their traits.
- Outline the advantages and disadvantages of insect sociality.
- Compare and contrast caste systems among the different social insects.
- Describe the unique social activities of bees, termites, ants and wasps.

18.1: Introduction

In the last two lectures we learnt about all the various insect orders. In this lecture you shall examine two orders namely: Isoptera (termites) and Hymenoptera (bees, ants and wasps), the "social" insects.

You shall learn the general traits and features of Isoptera and Hymenoptera. You shall discover that members of these two orders are unique in that they live in communities with well defined social organizations. The existence of different castes among the Isoptera and Hymenoptera will be elaborated. You will finally be able to compare the caste systems among the different social insects.

18.2: Overview of Social Insects

Most insects are not social, some aggregate or contact other members of their species for short periods to mate or for other functions. Some even dispense with mating and reproduce asexually.

Only a few groups are truly social.

All termites (Isoptera), some Hymenoptera (all ants, honey bees, sting less bees, bumble bees, and some members of other bee groups, and at least one wasp sp.).

True social insects, esp. the ants and termites, are dominant ecological groups.
Social life and organization occurs among the following insect groups:

18.2.2: Important definitions in relation to social insects

**Caste**
A specialized segment of the population of social insects, castes have different functions within the society and sometimes different morphologies. Castes have distinct divisions of labor.

**Eusocial**
Social systems characterized by parental care of young, overlap of generations, and reproductive division of labor. True sociality.

**Homeostasis**
The maintenance of a functional steady state in an organism or super organism

**Polymorphism**
Caste members are radically different in appearance, as results from environmental (food) differences

**Social Insects**
Insects that live cooperatively in colonies and exhibit a division of labor among distinct castes. e.g. termites, ants, bees, some wasps.

18.2.3: Traits of Eusocial Insects

1) Parental care of young (young couldn't survive without parental care)

2) Overlap of generations (essential for 1)

3) Reproductive division of labor, i.e.. there are egg-laying females and other females, may be other castes

For societies to persist, they must survive and reproduce more successfully than solitary individuals.

18.2.4: Castes among the social insects

- Reproductives - queen, king or drones
- Workers
- Soldiers
  - May be distinct morphological types, esp. in ants.
  - Lacking in wasps and bees.

18.2.4: Advantages and disadvantages of sociality

<table>
<thead>
<tr>
<th>Solitary Insects</th>
<th>Social Insects</th>
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</thead>
<tbody>
<tr>
<td>Advantages</td>
<td>Social Insects</td>
</tr>
<tr>
<td>Hide from predators</td>
<td>Colony productivity increased</td>
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<tr>
<td>No competition with others of your species</td>
<td>Group defense and alarm</td>
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<tr>
<td>Live in small spaces</td>
<td>Food gathering</td>
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<tr>
<td>Exploit small food resources</td>
<td>Nest building</td>
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<td></td>
<td>Care of young</td>
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<tr>
<td>Disadvantages</td>
<td>Intense predation, parasitism, disease</td>
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<tr>
<td>Lack of social benefits</td>
<td></td>
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</tbody>
</table>

ACTIVITY 18.1

Write true or false against the following statements:

1. The behavioral differences among castes is called Polytheism........  

2. Social insect live cooperatively in colonies and exhibit division of labor.....

3. All termites, all wasps, all Hymenoptera and all ants are social insects........
4. The majority of insects live in colonies.

5. Some insects even dispense with mating and reproduce asexually.

6. The soldier caste is lacking in bees and wasps.

7. All the different castes are morphologically similar among the social ants.

8. An advantage among solitary insects is that they can exploit small food resources.

9. Polymorphic insect forms are radically different in appearance, as a result from environmental (food) differences.

10. The reproductive castes are usually the soldiers and the workers.

18.3 Termites

Termites (often called white ants) differ from ants in being soft-bodied and usually light colored and having a broad joint between the thorax and abdomen. Ants are hard-bodied and have a narrow constriction between the thorax and abdomen. The three castes of termites are a winged reproductive, a wingless worker and a wingless soldier.

18.4: Honeybees

Honey bees have one of the most complex organizations in the insect world. Instead of lasting one season, their organization continues indefinitely. As many as 60,000 to 70,000 honeybees may be found in a single hive. Of these there are three different types (castes).

The three castes are a single queen, a few hundred drones (males) and the rest are workers (infertile females).

Honey Bees castes and their respective duties

Ø Reproductive Castes - queen and drone

Ø The Queen Bee

- Rules the bee hive
• Produces eggs to maintain the colony

• Lays all the eggs and regulates sex of offspring (parthenogenesis).
  o Unfertilized eggs -> males
  o Fertilized eggs -> females

• All members of the hive are the queen's progeny.

• The queen's pheromones identify hive members

Ø Drones - mate with new queens

Ø The Worker Bees

• Workers determine type of egg laid by queen.
  o Large cells receive unfertilized eggs that develop into males -- males haploid.
  o Smaller cells receive fertilized eggs that develop into females -- female's diploid.

• Workers determine whether a female egg develops into a reproductive or worker.
  o Workers receive royal jelly only their first three days.
  o Queens receive royal jelly throughout the larval stage.

The workers carry on all the activities of the hive except the laying of eggs. They gather nectar from flowers, manufacture honey, collect pollen, secrete wax, take care of the young and ventilate and guard the hive. Each worker appears to do a specific task in all this multiplicity of duties. Their life span is only a few weeks. One drone fertilizes the queen and stores sperm enough in her spermatheca to last her a lifetime. The drone is thereafter killed by workers. Thereafter the queen is concerned solely with egg laying. During the discharge of an egg, she is able to release or to withhold sperm, thereby determining whether or not the egg is fertilized. In so doing she effects the distinction between females and males. Males can only arise from unfertilized eggs and females from fertilized ones. A new queen mates during a mating flight. She then starts a new colony where she may lay as many as a million eggs. The queen can differentiate the larger beehive cells in which she lays her fertilized eggs (which develop into males) and the smaller worker cells in which she lays her unfertilized eggs. Whether larvae destined to become female will develop into a queen will depend on the kind of food it is fed by the workers. Workers that will become queens are fed royal jelly, a secretion from the salivary glands produced by workers only when there is no queen or when the queen is too old to produce enough pheromones or queen substance. The queen secretes from her mandibular glands the queen substance, which is licked off by the worker bees. This substance inhibits ovarian development in the workers and prevents them from becoming queens. In the absence of the queen from the hive the workers quickly begin rearing a new one. In an overcrowded colony the queen substance may not be distributed to all the workers so that reproductive individuals may swarm and a new queen mates with a drone and she starts another colony.

18.5: Social ants

Did you know that the science of studying ants is called Myrmecology?
There are thousands of species of ants found all over the world and in just about every type of land environment. Ants are common social insects that live in colonies. Some colonies have millions of ants. Each ant colony consists of the following:

Ø **Queen** - the queen begins her life with wings, which she uses while mating. After mating with a male ant or many males, she flies to her nesting area. She then loses her wings and spends her life laying eggs.

Ø **Workers** - Most ants in a colony are workers. Workers are the many sterile, wingless female worker ants that are the daughters of the queen. These workers collect food and feed members of the colony, defend the colony, and enlarge the nest.

Ø **Soldiers** - Soldiers are large workers (sterile females) who defend the colony and often raid other colonies.

Ø **Male reproductives** - These are small male ants that have wings. They fly from colony to mate with a queen. They die soon afterwards.

**Interesting things about ants!**

Some ants have a stinger at the tip of the abdomen, which can inject poisonous acid into the victim.

Ants can also bite using their jaws (mandibles).

Ants have evolved some striking patterns of economic behavior, such as making slaves, farming fungi (leafcutter ants are fungus farmers - they grow their own food), herding ant cows (aphids), sewing their nests together with silk, and using tools.

We have learnt that:

- Insects that exhibit complicated patterns of social instincts with marked division of labour among the different individuals are termed social.

- Social life and organization occurs among all termites (Isoptera), some Hymenoptera, (all ants, some bees, and some wasp species).

- For these insect societies to persist, they must survive and reproduce more successfully than solitary individuals. To achieve this, social insects provide parental care of young, have reproductive division of labor, i.e. there are females whose sole role is egg-laying and there is overlap of generations. Social insects also have complex modes of communications that ensures harmony within colonies.

- The three castes of termites are a winged adult reproductive, a wingless worker and a wingless soldier.

- The three caste in honey bee colonies are the queen, drone and worker. The queen bee rules such a colony and the drone is killed by workers after it has mated with the queen.

- Ants colonies, which can consist of as many as millions of ants are found all over the world. Each ant colony consists of the Queen, Workers, soldiers and male reproductives. Most ants in a colony are the wingless, sterile females who are the daughters of the queen. Soldiers are large workers (sterile females) who defend the colony and often raid other colonies. Male reproductives are small winged male ants that fly from colony to colony to mate with a queen and die soon afterwards.

- Some wasps are social and have a caste system of drones, workers and queens. There may be more than one queen in a wasp nest.

- There are differences in the social organization of Isoptera(termites) and Hymenoptera.

- Complex activities of insect societies include slavery, warefare, farming air conditioning.
Activity

1. Draw diagrams to differentiate the queen, drone and worker bees.
2. Outline the four different castes in an ant colony.
3. Mention three types of social wasps.
4. Write short notes on royal jelly.
5. Describe how bees form new colonies.
6. By means of a diagram differentiate the different termite castes.
7. Define the term myrmecology.

LECTURE 19: BENEFICIAL AND DESTRUCTIVE INSECTS

OBJECTIVES

At the end of this lecture you should be able to:

- Discuss the importance of insects in the ecosystem.
- Recognize the useful insects.
- Distinguish the insects that cause harm to crops, stored products etc.
- Identify parasitic insects that affect man and animals.
- State the major diseases of man and animals caused by insects.
- Outline the various methods employed in controlling insect pests.
- Show that insects are interwoven into the ecologic system and serve many useful as well as destructive roles.
- Appreciate that biocontrol of insect pests is one of the sound methods of ecologic management.

19.2: Role of insects in the ecosystem and human society

Insects are a dominant component of biodiversity in terrestrial ecosystems and play a key role in mediating the relationship between plants and ecosystem processes.

Although pest insects attract the most attention, many insects are beneficial to the environment and to humans.

Insects also produce useful substances such as honey, wax, lacquer and silk. Honeybees, have been cultured by humans for thousands of years for honey, although contracting for crop pollination is becoming more significant for beekeepers. The silkworm has greatly affected human history, as silk-driven trade established relationships between China and the rest of the world.

The wax is used in the making of shellac. Several kinds of silkworms especially Bombyx mori are reared for the production of silk.

Various dyes have been made from insects. Certain drugs such as cantharidin, is made from the Spanish fly, a blister beetle.

Cross pollination

Insects are important in the cross pollination of fruits and crops. The bees are indispensable in this respect. Insects and higher plants have evolved an intimate relationship of mutually advantageous adaptations. Insects exploit flowers for food and flowers exploit insects for pollination. Pollination is a trade between plants that need to reproduce, and pollinators that receive rewards of nectar and pollen. A serious environmental problem today is the decline of populations of pollinator insects, and a number of species of insects are now cultured primarily for pollination management in order to have sufficient pollinators in the field, orchard or greenhouse at bloom time.
3. Predation and Parasitism

Although mostly unnoticed by most humans, the most useful of all insects are insectivores, those that feed on other insects. Many insects, such as grasshoppers, can potentially reproduce so quickly that they could literally bury the earth in a single season. However, there are hundreds of other insect species that feed on grasshopper eggs, and some that feed on grasshopper adults. This role in ecology is usually assumed to be primarily one of birds, but insects, though less glamorous, are much more significant. Among these are ladybird beetles, aphid lions, ant lions, praying mantids, wasps and many others. For any pest insect one can name, there is a species of wasp that is either a parasitoid or predator upon that pest, and plays a significant role in controlling it.

Some insects lay their eggs on the larvae of injurious insects, and the parasitic larvae hatched from these eggs devour their host.

Cleaning the environment

Many insects, especially beetles, are scavengers, feeding on dead animals and fallen trees, recycling the biological materials into forms found useful by other organisms. The ancient Egyptian religion adored beetles and represented them as scarabeums.

Beetles and flies feed on decaying plant and animal refuse. The tumblebugs roll up balls of dung in which they lay their eggs; the developing larvae eat up the dung.

Source of food

In some parts of the world, insects are used for human food ("Entomophagy"), while being a taboo in other places. There are proponents of developing this use to provide a major source of protein in human nutrition. Since it is impossible to entirely eliminate pest insects from the human food chain, insects already are present in many foods, especially grains. Most people do not realize that food laws in many countries do not prohibit insect parts in food, but rather limit the quantity. According to cultural materialist anthropologist Marvin Harris, the eating of insects is taboo in cultures that have protein sources that require less work, like farm birds or cattle.

Insects are a source of food for birds and many other animals.

Research tools

Insects such as the fruit flies have been used in laboratories to carry out useful scientific investigations.

Fly larvae (maggots) were formerly used to treat wounds to prevent or stop gangrene, as they would only consume dead flesh. This treatment is finding modern usage in some hospitals. Insect larvae of various kinds are also commonly used as fishing bait.

Aesthetic value

Insects such as the butterflies are beautiful to watch.

Examples of beneficial insects

Some of the beneficial insects are shown in the picture below:- they include silkworm moth, Dobson fly larva, Dragon fly, Milkweed beetle, Whirling beetle, Honeybee, Bumblebee, Fig wasp, Rove beetle, Ladybird beetle, Burying beetle Ground beetle, Aphid lion, Robber fly Tachnid fly, Chalchid wasp, Chinch bug egg parasite, Syrphid fly and Ichneumon wasp.
19.4: Destructive insects

Many insects are considered pests by humans. Insects commonly regarded as pests include those that are parasitic (mosquitoes, lice, bedbugs), transmit diseases (mosquitoes, flies), damage structures (termites), or destroy agricultural goods (locusts, weevils).

Injurious insects affect man in some of the ways stated below:

1. **Agricultural pests**: Nearly all cultivated crops are bothered to some extent by insects. Insects that eat and destroy crops include grasshoppers, corn borers, cotton boll weevils, scales, armyworms, fruit flies, and many others. The amount of damage is usually enormous.

2. **Nuisance**: Flies are normally a nuisance and can cause discomfort during man's activities. The night flies can interrupt sleep. Some insects inflict painful bites.

3. **Venomous bites**: Insects such as bee, wasps, inject painful venoms with their stings.

4. **Parasitism**: Insects such as lice, fleas, and bed bugs are ectoparasites of man and other animals. The larvae of blow flies, warble flies, and botflies are internal parasites of animals; Infestation of tissues of man and animals is by fly larvae causes an undesirable condition termed **Myiasis**.

5. **Disease transmission**: Among the chief vectors of disease are mosquitoes, which transmit malaria, yellow fever, and filariasis; houseflies, which can transmit typhoid, dysentery, and other diseases; tse-tse flies, which transmit animal and human
trypanosomiasis. Other insects, which can transmit diseases, include sand flies, black flies, fleas, and lice. The list is not exhaustive.

6. Household pests: Larval stages of moths such as the cloth moth build their cocoons from fabrics, upon which they feed and ruin. Carpet beetles are equally destructive. Weevils, cockroaches damage stored food products; ant and termites can cause serious damage to household fittings and timber.

19.5: Control of destructive insects

Many entomologists are involved in various forms of pest control, often using insecticides, but more and more relying on methods of biocontrol.

Human attempts to control pests by insecticides can backfire, because important but unrecognized insects already helping to control pest populations are also killed by the poison, leading eventually to population explosions of the pest species.

The control of insects is one of the problems confronting man in his search for sound methods of ecologic management. Insects are interwoven into the ecologic system and serve many useful as well as destructive roles. The big problem is to find ways of controlling only the destructive insects without destroying the rest. Two kind of tactics are being emphasized in efforts no insect control; tactics that involve developing animals and plants that are resistant to insect pests and tactics that directly destroy the insect pests in question. Some of the current methods being applied to control certain insects include the following:

1. Chemical control
2. Physical control
3. Biological control
   a. Viruses
   b. Natural predators
   c. Sterile insect technique
   d. Insect sex attractants

LECTURE 20: INSECT SUCCESS, ORIGIN, BEHAVIOUR AND ECOLOGY

Insects are enormous in terms of numbers and have also undergone adaptive radiation that enables them to live in a wide variety of habitats. Their success is attributed to a number of factors, which include the following:

Ø Possession of the Exoskeleton: The exoskeleton protects insects from the harsh environment, natural enemies and desiccation.

Ø Adaptability to wide range of habitats: insects can live in nearly all types of places except the deep sea.

Ø Varied food source: The ability to utilize a wide variety of foods enables insects to live successfully in various types of habitats. They have varied mouthparts suitable for different types of foods.

Ø High reproductive potential: Insects have very short life cycles. This results in very large number of progeny within a short time. Some such as bees and aphids can even reproduce parthenogenetically. This ensures survival of the species even in harsh environment.

Ø Communal life: The ability of some insects to live together in colonies has been an important factor in their success. The social organization in Isoptera and hymenoptera results in efficient division of labour among the individuals for the benefit of the whole colony.

Ø Complex behavior: Insects have some complex behaviour patterns that ensures their survival; for example, some insects will lay eggs only with view to the future needs of the young. Males of the family Empididae (Diptera) offer well prepared food to females as a present as part of the mating ritual, a sort of a bribe to ensure her cooperation. Some insects can communicate information on food source and danger to members of their community.

Ø Small body size: Insects require only small amounts of food due to their relatively small size. They are not always visible and can hide from enemies.

Ø Sensitive sense organs: Insects are able to respond quickly and favorably to changes in their environment.

Ø Defense mechanisms: Insects have interesting and effective means of defense from enemies such protective coloration, stings
Ø Possession of wings: The power of flight has greatly contributed to the success of insects by

- Allowing them access to many habitats
- Permitting maximum dispersal (thus reducing competition and overcrowding)
- Making escape from natural enemies possible and undesirable situations.
- Enabling them to search for food over long distances.

Are you aware that Insects are amongst the most successful terrestrial animals? Discuss this statement.

20.2: Origin of insects

The relationships of insects to other animal groups remain unclear. Although more traditionally grouped with millipedes and centipedes, evidence has emerged favoring closer evolutionary ties with the crustaceans.

One theory suggests that insects arose from the ancestral stock of the class Symphyla in the Pancrustacea theory insects, together with Remipedia and Malacostraca, make up a natural clade.

Most entomologists, however, believe that insects probably evolved from worm-like sea creatures. The study of fossilized insects is called paleoentomology.

Fossil records indicate that the first insects were wingless, dated back to the Devonian period, which lasted from 410 million to 355 million years ago.

By early Bashkirian age, about 350 million years ago, insect species were already diverse and highly specialized by this time, with fossil evidence reflecting the presence of more than half a dozen different orders. Thus, the first insects probably emerged earlier in the Carboniferous period, or even in the preceding Devonian. Research to discover these earliest insect ancestors in the fossil record continues.

The origin of insect flight remains obscure but it is generally believed that approximately 200 to 350 million years ago (late Carboniferous period) insects developed wings and the ability to fly. The early wings were primitive and could not be folded.

Insects were therefore dominant in the Carboniferous and Permian period (290-250 million years ago). Late Carboniferous and early Permian insect orders include both several current very long-lived groups and a number of Paleozoic forms. During this era, some giant dragonfly-like forms reached wing spans of 55 to 70 cm, making them far larger than any living insect. Also their nymphs must have had a very impressive size. This gigantism may have been due to higher atmospheric oxygen levels that allowed increased respiratory efficiency relative to today.

Most extant orders of insects developed during the Permian era that began around 270 million years ago. Towards the end of the Permian period, Carboniferous insects became extinct and other species appeared. This period is referred to as the "Permian-Triassic extinction event", the largest mass extinction in the history of the earth, around 252-205 million years ago.

By the Jurassic period, which lasted from about 213 to 145 million years ago, all present-day insect orders had appeared.

The remarkably successful Hymenopterans appeared in the Cretaceous period (135-65 million years ago) but achieved their diversity more recently, in the Cenozoic era. Many modern insect genera developed during the Cenozoic era (at least 65 million years). Insects from this period on are often found preserved in amber, often in perfect condition. Such specimens are easily compared with modern species.

A number of highly-successful insect groups evolved in conjunction with flowering plants, a powerful illustration of co-evolution.

20.4: Insect ecology
Ecology is the study of the interrelationships between organisms and their environment. An insect's environment may be described by physical factors such as temperature, wind, humidity, light, and biological factors such as other members of the species, food sources, natural enemies, and competitors (organisms using the same space or food source).

You learnt in lecture 19 that although pest insects attract the most attention many insects play varied roles in the ecosystem. An understanding or at least an appreciation of these physical and biological (ecological) factors and how they relate to insect diversity, activity (timing of insect appearance or phenology), and abundance is critical for successful pest management.

Some insect species have a single generation per season (univoltine), while others may have several (multivoltine). The striped cucumber beetle, for example, over winters as an adult, emerges in the spring, and lays eggs near the roots of young cucurbit plants. The eggs hatch, producing larvae that emerge as adults later in the summer. These adults over winter to start the cycle again the next year. In contrast, egg parasitoids like Trichogramma over winter as immatures within the egg of their host. During the summer they may have several generations.

Insects adapt to many types of environmental conditions during their seasonal cycle. To survive the harsh winters, cucumber beetles enter a dormant state. While in this dormant state, metabolic activity is minimal and no reproduction or growth occurs. Dormancy can also occur at other times of the year when conditions may be stressful for the insect.

It is often better to consider insects as populations rather than individuals, especially within the context of an agro ecosystem. Populations have attributes such as density (number per unit area), age distribution (proportion in each life stage), and birth and death rates. Understanding the attributes of a pest population is important for good management. Knowing the age distribution of a pest population may indicate the potential for crop damage. For example, if most of the striped cucumber beetles are immatures, direct damage to the above ground portions of the plant is unlikely. Similarly, if the density of a pest is known and can be related to the potential for damage, an action may be required to protect the crop. Information about death rates due to natural enemies can be very important. Natural enemies do nothing but reduce pest populations and understanding and quantifying their impact is important to effective pest management. This is all the more reason to conserve their numbers.

### 20.4.1. Factors contributing to the success of Insects

Insects are enormous in terms of numbers and have also undergone adaptive radiation that enables them to live in a wide variety of habitats. Their success is attributed to a number of factors, which include the following:

- **Possession of the Exoskeleton:** The exoskeleton protects insects from the harsh environment, natural enemies and desiccation.
- **Adaptability to wide range of habitats:** Insects can live in nearly all types of places except the deep sea.
- **Varied food source:** The ability to utilize a wide variety of foods enables insects to live successfully in various types of habitats. They have varied mouthparts suitable for different types of foods.
- **High reproductive potential:** Insects have very short life cycles. This results in very large number of progeny within a short time. Some such as bees and aphids can even reproduce parthenogenetically. This ensures survival of the species even in harsh environment.
- **Communal life:** The ability of some insects to live together in colonies has been an important factor in their success. The social organization in Isoptera and hymenoptera results in efficient division of labour among the individuals for the benefit of the whole colony.
- **Complex behavior:** Insects have some complex behaviour patterns that ensures their survival; for example, some insects will lay eggs only with view to the future needs of the young. Males of the family Empididae (Diptera) offer well prepared food to females as a present as part of the mating ritual, a sort of a bribe to ensure her cooperation. Some insects can communicate information on food source and danger to members of their community.
- **Small body size:** Insects require only small amounts of food due to their relatively small size. They are not always visible and can hide from enemies.
- **Sensitive sense organs:** Insects are able to respond quickly and favorably to changes in their environment.
- **Defense mechanisms:** Insects have interesting and effective means of defense such protective coloration, stings
- **Possession of wings:** The power of flight has greatly contributed to the success of insects by

- Allowing them access to many habitats
- Permitting maximum dispersal (thus reducing competition and overcrowding)
- Making escape from natural enemies possible and undesirable situations.
- Enabling them to search for food over long distances.

FAOyiyeke
In this lecture we have learnt that:

- The study of fossilized insects is called **paleoentomology**. And insects first appear in the fossil record during the Carboniferous age, about 350 million years ago.
- Insects have evolutionary relationships with either annelids, crustaceans, millipedes or centipedes. It generally believed that insects evolved from some wingless ancestor.
- Although pest insects attract the most attention many insects play varied roles in the ecosystem.
- Many insects possess refined organs and mechanisms for complex communication hence complex behavior. Pheromones found in ant trails, territorial markers, and sex attractants play a key role as the chemical signals that elicits certain behavior patterns such as aggregation, courtship, etc. The social insects are so tightly integrated that they are sometimes considered super organisms.
- Among the many complex behavior patterns displayed by insects are phenomenon such as stridulation, bioluminescence, and trophallaxis, visual and chemical communication.
- Several factors have contributed to the success of Insects, among them being; Possession of the exoskeleton and wings, effective defense mechanisms, sensitive sense organs, small body size, varied food source, communal life, complex behavior, high reproductive potential and adaptability to a wide range of habitats.

**Activity**

*These are important review questions. You will find the answers in the text.*

- Write short notes on some of the conventional theories with respect to the origin of insects.
- Outline the factors that have contributed to the success of insects.
- Insects display some complex behavior patterns. Discuss this statement with specific examples.

### 20.3 : Insect behaviour/ complex activities of insect societies

#### 20.3.1: Slavery

A biological, not a cultural trait that is wide-spread among ants. Most ant battles you see are actually slave raids. Ant slavery is unique because ant slavery is usually between species, unlike human slavery.

**Slave making ants**

- Capture larvae and pupae of another species.
- Carry them back to their own nest where:
  - They acquire the nest odor.
  - Develop into adults and act as workers for their new colony.

Some slave making ant species are incapable of surviving without slave workers. They are no longer able to collect food or feed their immatures or themselves.

FAOyieke
20.3.2: Warfare

Embodies restless aggression, territorial conquest, and genocidal annihilation of neighboring colonies. Ants war with their own and other species and use a variety of tactics.

**Imported Fire Ant, Solenopsis sp. invicta vs. the Woodland Ant, Pheidole dentata**

The fire ants have colonies hundred times larger than the woodland ant and whenever they discover a woodland ant colony they completely destroy it. Yet woodland ant colonies are abundant around fire ants. Whenever, a woodland worker discovers a fire ant scout soldiers are so rapidly deployed that the scout rarely makes it back to its colony. The soldiers do not sting or spray poisons like many ants but rely on large mandibles to cut their opponents into pieces. If despite this the woodland nest is discovered the soldiers fall back to form a short perimeter around the nest, which keeps the invading, fire ants at bay temporarily. The colony evacuates the nest and after the battle and the fire ants have departed, they will return and reclaim their nest.

20.3.3: Farming

Many ants keep insect livestock in the order Homoptera. Commonly seen in our area are ants tending aphids. The ants herd the aphids and protect them from predators and parasites, in turn, the aphids reward the ants by providing droplets of sweet and nourishing honeydew. Besides aphids, scale insects, other Homoptera, are farmed and some insects in other orders. This is a good example of symbiosis.

Other ants and some termites are gardeners. They collect plant material, bring it into their nests, compost it, and use it to grow fungi, which they feed on. Leafcutter and parasol ants are examples.

20.3.4: Air conditioning

Some social insects are able to maintain steady state conditions in their colonies or nests, e.g. in temperature and humidity. This is called **homeostasis** and is essential for colony health.

**Honey bees**

- Ventilate their hives - if too hot, wax melts.
- Cluster to stay warm in the winter - if too cold, individuals die.

**Termites**

- Soft bodied, very susceptible to desiccation.

20.3.5: Dances

Bees have developed a language expressed by a sort of dancing ritual by which workers can inform the other workers in the hive the whereabouts, distance to, and type of food source they have discovered. There are two types of dances the wagging dance and the round dance.

20.3.1 Light production

The production of light by living organisms is called bioluminescence. It may be for sex signaling, for kin recognition, for frightening enemies, for allurement, or to act as a lamp to guide the animals' movement. In fire flies light production functions to attract the opposite sex.

20.3.2: Reactions to chemical signals

The chemical signals that insects produce and use to communicate are called Pheromones. Many example of chemical communication are known in insects. A few striking examples are as follow; the male of some moths can locate females by means of air-borne substances detected from a distance as great as 2.7 miles. Substances deposited on the ground by ants returning from foraging trips serve as trail
marker for other ants. More remarkable is the fact that a substance produced by the painted ant will be carried live out of the nest as it struggles.

If an ant colony is attacked the other members of the colony respond by assuming aggressive postures or attacking the intruder. The workers are stimulated by pheromones from the mandibular or anal glands, which is released by any individual being attacked. Pheromones can also induce gathering, mutual grooming and trophallaxis in ants. Trophallaxis refers to mutual exchange of food amongst insects, particularly the social insects.

Insect pheromones

**Pheromones are substances that are secreted onto the outside of the body where they influence the behavior of other members of the same species.**

Insects possess very refined organs of perceiving pheromones that surpass even the human perception. For example, some male moths have a specialized sense of smell that enables them to detect the pheromones of the female moths over distances of several kilometers! They are some times called “social hormones”. They are chemical communication signals. Insect pheromones include odor trails by ants, sex attractants, alarm substances, and territorial markers. Pheromones are most numerous in the social insects.

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If an ant colony is attacked the other members of the colony respond by assuming aggressive postures or attacking the intruder. The workers are stimulated by pheromones from the mandibular or anal glands, which is released by any individual being attacked. Pheromones can also induce gathering, mutual grooming and trophallaxis in ants. Trophallaxis refers to mutual exchange of food amongst insects, particularly the social insects.

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20.3.3: Stridulation or Sound production

Stridulation is the production of sound by rubbing two parts of the body together; this mechanism is best known in crickets, grasshoppers, and cicadas. Other insects which stridulate include Black imported fire ant (Solenopsis richteri) and larval Lucanidae (stag beetle), Passalidae (Bessbug), and Geotrupidae (earth-boring dung beetles).

Sound production are concerned with calling, courtship, copulation, aggression and alarm. Sound production is especially notable in grasshoppers, crickets, and cicadas. Crickets produce sounds by rubbing of the front margin against the vein of the forewing. Each species of cricket produces a number of songs, which differ from the songs of other species. The static-like sounds of cicadas, which serve to aggregate individuals, are produced by vibrations of special chitinous abdominal membranes. Grasshoppers produce sound by the rubbing of the forewing against the hind femur. The role of songs in courtship has been greatly studied in grasshoppers; where the female responds to the male only at certain times in some insect groups only one sex produces sound, to which the opposite sex responds accordingly.
20.3.4: Visual communication

Visual communication is simply the influencing of one individual by the behavior of another. Among the most interesting behavior patterns is the power of many insects have of finding their directions and communicating the same to others. Honey bees for instance have a bee language for conveying information on food source to others members of the hive. The illustrations below show the two types of bee dances that communicate the source, distance and location of the food.

20.3.4.1: The wagging dance

If the food source is more than 100 meters away from the hive, a honey bee performs the wagging dance illustrated below. The direction of the food source is indicated by the direction of the waggle dance in relation to the sun. This dance is roughly in the pattern of a figure eight that she makes against the vertical side of the comb. In the performance of this act she waggles her abdomen from side to side in a characteristic manner. She repeats the dance over and over, the number of dances decreasing per unit time the farther away the food source. The direction of the food source is also indicated by the direction of the waggle dance in relation to the position of the sun. When the waggle dance is upward on the comb, the source of food is toward the sun. A waggle run downward on the comb, indicates that the food source is opposite the position of the sun. If the food source is at angle to the sun, the direction of the waggle dance is at a corresponding angle. Insects thus make use of polarized light.

During a dance other bees keep in contact with the scout bee with their antennae, and each performance results in several bees taking off in search of the food.

20.3.4.2: The round dance

When the food source is less than 100 meters from the hive, the pattern of dance is less complex. In this case the scout bee simply turns round in a circle first to the right and then to the left, a performance she repeats several times. She is able in this way to convey to other bees the information to seek around the hive food of the same same odors she bears.
20.3.5. Rhythms of Activity (Biological clock)

Some insects are more active at night (nocturnal), others in daylight (diurnal), and still others in dim light (crepuscular). Locusts are active during daylight and almost completely inactive at night, while mosquitoes, cockroaches and other insects are wholly nocturnal in their flight activity. The recurring rhythmic activities is determined by some ‘biological clock’. The timing of the activities is believed to be controlled by both external and internal factors.

ACTIVITY 20.2

Write True or False against the following statements.

1. The bee dances communicate the source, distance and direction of the food

2. Insects that are active in dim light are described as being diurnal.

3. Mosquitoes and cockroaches are largely nocturnal.

4. The timing of the activities is believed to be controlled by both external and internal factors.

5. Each species of cricket produces a number of songs, which differ from the songs of other species.

6. In fireflies, light production functions to attract the opposite sex.

7. If the food source is less than 100 meters away from the hive bees perform the wagging dance.

8. Fossil records indicate that the ancestral insects were wingless.

9. The study of fossilized insects is called paleontology.

10. Bees perform the round dance when the food source is more than 100 meters from the hive.
ACTIVITY 20.3

Review questions

Write an essay on social insects.

1. Describe the basic insect mandibulate mouthpart and show how the honeybee and butterfly mouthparts have been derived from it.
2. Discuss respiration in aquatic insects.
3. Write an essay on insect growth and metamorphosis.
4. Outline any two of the following: The insect Digestive, Circulatory, Nervous, Excretory or Reproductive system.
5. Discuss “Insect classification and Morphology”

APPENDIXES

chapter one?

ANSWERS TO TEXT QUESTIONS

CHAPTER ONE
Activity 1.1
- Species genus, family, order, class phylum kingdom
- Entomology
- Taxonomy
- Taxon
- Thirty
Activity 1.2 A diagram
Activity 1.3 A table
Activity 1.4 Answers in text

chapter two

Activity 2.1
1. Epicuticle
2. Endocuticle
3. Exocuticle
4. Epidermis
Activity 2.2
1. Sclerotization
2. Foregut, hindgut and trachea
3. Epicuticle
4. Resin
Activity 2.3. Answers in text

chapter three

Activity 3.1
No. 1. Yes
2. Plates covering the insect body
3. Head capsule
Activity 3.2
No. 1 A Sketch
Activity 3.3
1. Vertex - Top of the insect head
2. Clypeus - Upper mid portion of insect head
3. Beetle larvae - Prognathous
4. Gena - Cheek
5. Grasshopper - Hypognathous
6. Aphid - Opisthognathous
7. Frons - Face of an insect
8. Labrum - Insect upper lip
9. Ocelli - Simple eyes
10. Sulcus - Lines
11. Sclerites - Plates
12. Sensory - Antennae
Activity 3.4 Answers in text

chapter four

Activity 4.1
chapter five

Activity 5.1
No.1 mandibles, maxillae, Labium, Labrum, Hypopharynx

Activity 5.2
No. 1 Neuroptera (ant lions), Hymenoptera (honey bees)
No. 2 Cutting floral tissues and nest const
No. 3 Labium and maxillae
No. 4 Yes
No. 5 Laciniae

Activity 5.4
No. 1 Haematophagous
No.2 Retractable or coiled when not in use
No 3 Sponging or lapping

Activity 5.5. Answers in the text

chapter six

Activity 6.1
No. 1. Prothorax, Mesothorax, metathorax
No. 2. Tergites sternites, pleurites
No. 3 Lateral

Activity 6.2
Answers in the text

Activity 6.3
No. 1 Corbicula
No. 2 Swimming
No. 3 3 pairs
No. 4 Pronotum
No. 5 Odonata
No. 6. Calcar

Activity 6.4
No. 1. Crawling, Grasping, Jumping, Pollen carrying Digging, Swimming
No. 2 Sound production, Silk production, auditory

chapter seven

Activity 7.1
No. 1. A drawing

Activity 7.2

Activity 7.3
No. 1.
1. Fleas
2. Lice
3. Bedbugs

No. 2
- Thrips - Fringed
- Lacewings - Lacelike
- Stick insect - Brachypterous
- Moths and butterflies – Scales

No. 3
- Hemelytron
- Elytra
- Halteres
- Tegmina

No. 4
Wings of insects are flattened outgrowths of the body wall. Wings of birds are appendages

chapter eight

Activity 8.1 - Self-evaluation

Activity 8.2 - self-evaluation

Activity 8.3
No. 1. NO  No. 6 Yes
2. yes  7 NO
3. Yes  8 NO
4. NO  9. Yes
5. Yes 10. No

Activity 8.4
1. Answer in text
2. Answers in text
3. Defense, Copulation, Locomotion, Food gathering, Sense organ
4. Taxonomic insect to species.

chapter nine
Activity 9.1
No. 1. Parasitism, predation
Saprophagous, Haematophagous, Phytophagous
2 Termites - Cultivation of fungi
3.(a) Tsetse flies - Males and females
(b) Mosquitoes - Females only.
Activity 9.2
No. 1. Gut, gastric system, alimentary canal
2. Foregut, Midgut and hindgut
3. (a) Ventriculus - Midgut
(b) Proctodaeum- Foregut
4. Enzymes produced by symbiotic flagellates
5. Diverse diets
Activity 9.3 Self-evaluation

<table>
<thead>
<tr>
<th>Activity 10.1</th>
<th>Activity 11.1</th>
</tr>
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<tbody>
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</tbody>
</table>

Activity 11.2 Answers in text

chapter twelve
Activity 12.1
1. Spiracles 6. Taenidium
2. Intima 7. Oxygen, Carbon dioxide
3. Air Sacs 8. Tracheoles
4. Taenidium 9. Diffusion
5. Trachea 10. Air Sacs
Activity 12.2 - Self-evaluation
Activity 13.1 Answers in the text
chapter thirteen
Activity 13.1 Answers in the text
chapter fourteen
Activity 14.1. Answers in the text

chapter fifteen
No. 1  (a) Ametabola - Metamorphosis
e.g. Thysanura egg - Young-adult
(b) Hemimetabola - Incomplete metamorphosis
e.g Locust, egg - nymph - adult
© Holometabola - Complete metamorphosis
e.g Housefly, egg - larva-pupa-adult
No. 2  (a) Erucaform or Polypod, caterpillar-like
   (a) Scarabaeiform, grub-like
   (b) Campaeform or oligopod, elongated, flattened and active
   (c) Vermiform, maggot-like
   (d) Elateriform, wireworm-like
No. 3  (a) Exarate pupa - pupa with free appendages
   (b) Ob rect pupa - pupa with appendages glued onto the body
No. 4  (a) Instar - Stages between moult
   (b) Ecdysis - Shedding of the exoskeleton
© Naiad – Aquatic nymphal stage of a hemimetabolous insect
(d) Heteromorphosis – Occurs when successive larval stages are quite different in form and habits, common in predaceous insect

chapter sixteen
Activity 16.1
No. 1.
(a) Apterygota – Wingless insect
(b) Pterygota – Winged insect
© Exopterygota – Subclass consisting of insects whose wings develop outside the body and thus have externally visible wing buds in the late nymphal and pupal stages
(b) Endopterygota - Subclass consisting of insects whose wings develop inside the body and thus not visible until after metamorphosis.
No. 2
(a) Lepidoptera
(b) Anoplura
(c) Mallophaga
(d) Coleoptera
(e) Hymenoptera
(f) Hymenoptera
(g) Diptera
(h) Homoptera
(i) Dictyoptera
(j) Hemiptera
(k) Isoptera
(l) Diplura
No. 3 (a) Lice – Anoplura
(b) Fleas – Siphonaptera
(c) Bedbugs – Hemiptera
No. 4 Diptera
chapter seventeen
Activity 17.1
1. Thysanoptera
2. Thysanura
3. Pscoptera
4. Strepsiptera
5. Plecoptera
6. Protura
chapter eighteen
Activity 18.1
No. 1. True 6. True
2. True 7. False
3. False 8. True
4. False 9. True
5. True 10 False
Activity 18.2 Answers in the text
8. Activity 18.3
9. No 1. Bees, ants, termites, wasps
10. 2. Queen, King, worker, Soldier
11. 3. Answers in the text
12. 4. Slavery and warfare, herding and farming, air conditioning, Trophallaxis
chapter nineteen
Activity 19.1
No. 1. (a) Source of food
(b) Aesthetic value
(c) Research
(d) Biological control
(e) Production of silk, honey, bees and wax
(f) Pollination
(g) Soil Aeration
(h) Scavengers clean the environment
2. (a) Pests of crops, stored products
(b) Disease vectors
(c) Nuisance
3. Infestation of animal tissues by fly larvae (Myiasis)
2. Answers in the text
chapter twenty
Activity 20.1
No. 1 Chemical substances produced by insects to elicit a response by others of the same species
No. 2 Light production by living organisms
No. 3 Sound production by the rubbing of one part against another by insects
Activity 20.2
No. 1 True, No. 2 False, No. 3 True, No. 4 True ,No. 5 True ,No. 6 True ,No. 7 False, No. 8 True, No. 9 True ,No.10 False